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A Study of Overnight Lighting in Non-Domestic Buildings

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Abstract

The use of electricity, specifically through overnight lighting in non-domestic buildings, is a cause for increasing carbon dioxide emissions. Through our project, we developed and implemented a methodology for nighttime observations and studied the reasons for overnight lighting in commercial buildings. Analysis of our data led to an estimation of power consumption from overnight lighting. Our sponsor will combine our results with existing data to develop a model for predicting carbon dioxide emissions in the United Kingdom.

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Executive Summary

Global warming and climate change are growing issues throughout the world. The increasing level of greenhouse gases, specifically carbon dioxide, in the atmosphere is one of the greatest contributors to climate change. Since the industrial revolution, the amount of carbon dioxide in the atmosphere increased by over 30 percent (Intergovernmental Panel on Climate Change [IPCC], 2001). Thus, human activity likely contributes to the increase of carbon dioxide. With an increasing world population, the amount of carbon dioxide emissions will continue to grow. Government funded organizations, along with charity and privately funded organizations, are taking a step forward in reducing the increasing emissions by implementing policies and creating programs to help reduce the effects of global warming.

Commercial office buildings are one of the major contributors to emissions. Among the many activities that consume energy in commercial buildings, lighting is one of the major end uses of energy. With this fact in mind, and the lack of available information on energy use in commercial buildings, Carbon Reduction in Buildings (CaRB), a program funded by the Carbon Vision Buildings Partnership (CVB), began a four-year socio-technical, longitudinal study of carbon use in buildings (CaRB, 2004). The data we collected contributes to efforts in reducing carbon emissions in buildings throughout the United Kingdom. Our role in CaRB's overnight lighting study was to create a methodology for studying overnight lighting as well to collect data and estimate the resulting power consumption.

Before we began conducting our project, we tested our methods using a simple pilot study. After completing the pilot study, we used our newly refined methodology to conduct our full study, which consisted of both daytime and nighttime observations. During the day we photographed buildings and recorded any contact information we found. Using the recorded contact information we then communicated with building managers through phone calls and e-mails, requesting the opportunity to perform interviews. During the night, we took photographs of the same buildings, as well as counted the total number of windows and the total number of illuminated windows. Through the interviews we conducted, we gained information about the buildings that we could not obtain from street level observations.

Once we received the data, our first task was to compile and organize the pictures using a simple computer program that we developed. After arranging the pictures, we entered our observations into a data spreadsheet using Microsoft Excel. By organizing the data this way, we

were able to efficiently analyze the information and give CaRB detailed data, which they can incorporate into their ongoing study.

Some buildings only had lights on in certain areas of the building during the night. For example, only the stairwells and lobbies had lights on in some of buildings. We defined the overnight lighting in areas such as stairwells, doorways, in front of lifts or in front of security cameras to be lighting use. In other buildings we noticed all of the lights were on without any signs of people; we classified these buildings as wasting lighting energy. However, we did find some buildings lit up at night with people present inside and we classified this as use, opposed to waste. While most buildings do leave at least some lights on at night, our study assessed whether overnight lighting is in fact a wasteful consumption of energy.

With the completion of our project, we quantified the amount of lighting used at night. We also made an estimation of total power consumption for all of the buildings. Based on our results, the average total power consumption for the 140 buildings per night was 850 kW. Our results showed us that while studying a wide range of buildings, many buildings varied in lighting use. We found some buildings leave lights on for the mere purpose of security, while others left them on for no reason at all. Finally, we provided recommendations for future research and operational suggestions for field work.

Table of Contents

Abstract i
Acknowledgements ii
Authorship Page iii
Executive Summary v
Table of Contents vii
Table of Figures ix
Table of Tables x
Introduction 1
Background 3
  Climate Change 3
  Current Efforts to Reduce Carbon Dioxide Emissions 7
  Impact of the Non-Domestic Building Stock 10
Methodology 16
  Review of Existing Data-Gathering Techniques 17
  Global Action Plan Interview 17
  Area of Study and Building Selection 18
  Pilot Study 19
  Gathering Building Specifications and Lighting Use Data 20
    Daytime Observations 20
    Nighttime Observations 21
    Interviews 22
    Detailed Nighttime Observation 22
  Compiling and Analyzing Data 23
    Organization of Data Using Excel 23
    Organization of Photographs Using Python 24
Results and Discussion 27
  Results 27
    Results of the Pilot Study 27
    Quantitative Results 28
    Qualitative Results 30
  Discussion 31
    Quantitative Results and Power Consumption Estimates 31
    Patterns in Overnight Lighting 33
    Comments on Applied Methods of Gathering Data 40
    Use and Waste of Overnight Lighting 41
Conclusions 45
Recommendations 47
  Research Recommendations for Future Studies 47
  Operational Suggestions for Field Work 48
References 51
Appendix A: Sponsor Description 54
Appendix B: Minutes from Interview with Global Action Plan 55
Appendix C: Map of Area of Study 56

Northern Half of Area of Study ... 56
Southern Half of Area of Study ... 57
Appendix D: Field Data Collection Sheet ... 58
Appendix E: Building Manager Interview Questions ... 59
Appendix F: Photo Tracking Sheet ... 60
Appendix G: Computer Program for Organizing Observation Photos ... 61
Appendix H: Pilot Study Observation Data ... 64
Appendix I: Building Identification ... 65
Appendix J: Physical Characteristics of Buildings ... 69
Appendix K: Building Data from Daytime Observations ... 73
Appendix L: Window Data from Daytime Observation ... 77
Appendix M: Quantitative Data from Nighttime Observations ... 81
Results from Monday, January 22, 2007 ... 81
Results from Monday, January 29, 2007 ... 83
Results from Thursday, February 8, 2007 ... 85
Results from Monday, February 12, 2007 ... 87
Appendix N: Power Consumption for Lighting ... 89
Based on Data from Monday, January 22, 2007 ... 89
Based on Data from Monday, January 29, 2007 ... 91
Based on Data from Thursday, February 8, 2007 ... 93
Based on Data from Monday, February 12, 2007 ... 95
Appendix O: Results from Detailed Observation ... 97
Field Notes from the Observation ... 97
Quantitative Results from the Observation ... 99
Appendix P: Building Manager Interview Responses ... 101
Interview 1 ... 101
Interview 2 ... 103
Interview 3 ... 105
Interview 4 ... 107
Appendix Q: Relevant Field Notes ... 109
Notes on People Visible in Buildings during Observations ... 109
Notes on Illuminated Stairwells ... 109
Appendix R: Commercial Lighting Energy Targets ... 110

Table of Figures

Figure 1: Deviation from Mean Global Temperature (°C) from 1880 to 2000 4
Figure 2: The Greenhouse Effect 6
Figure 3: Energy Uses in UK Commercial Sector in 2000 13
Figure 4: Formula for quantifying energy use from lighting employed by EIA 15
Figure 5: Illustration of Our Definition of a Single Window 21
Figure 6: Visual depiction of the photograph directory structure 25
Figure 7: Equation for Estimate of Power Consumption from Overnight Lighting 32
Figure 8: Frequency Distribution of Illuminated Windows 34
Figure 9: Scatter Plot of Floor Space and Percent Illuminated Windows 37
Figure 10: Comparison of Overnight Lighting by Street 39

Table of Tables

Table 1: Projected UK CO_2 Emissions by sector (Million tons of Carbon) 7
Table 2: Summary of Quantitative Results 33
Table 3: Comparison of Buildings by Size 36
Table 4: Illuminated Windows by Time of Night 38
Table 5: Comparison of Overnight Lighting in Buildings with Air Conditioning 38

Introduction

Global warming is an issue facing all nations of the world. A global consensus is forming that human activity contributes to rapidly increasing levels of certain greenhouse gases, specifically carbon dioxide. Since the start of the Industrial Revolution, the amount of carbon dioxide in the atmosphere has increased by over 30% (Intergovernmental Panel on Climate Change [IPCC], 2001). A certain amount of carbon dioxide is necessary in the atmosphere to support life. However, the presence of an abundance of the gas causes the atmosphere to trap too much heat at the surface, which in turn causes the ambient temperature to rise.

Fluctuations in global temperatures can result in widespread effects. For example, a seemingly small temperature change, as little as 1.1 degrees Celsius, caused the Little Ice Age from the 1500s to the mid 1800s (Environmental Protection Agency [EPA], 2006). An increase in global temperature has secondary effects as well, from increased sea levels to severe climate change. According to current greenhouse effect predictions, the average temperature will rise an additional 2 to 6 degrees Celsius over the course of the next century, which is more than double the temperature change that caused the Little Ice Age (IPCC, 2001). The potential climate changes could be a significant threat, as they could result in widespread droughts and stronger, more frequent hurricanes.

Carbon dioxide, a byproduct of combustion reactions, is the greatest contributor to the greenhouse effect, but it is also necessary for present-day life forms to exist on Earth. Its sources include animals, forest fires, and power plants. Alternatively, living plants remove carbon dioxide from the atmosphere in order to produce sugar and oxygen through photosynthesis. To maintain current levels of carbon dioxide, the amount produced by animals and other sources must equal the amount consumed. However, humankind has added more carbon dioxide to the atmosphere through industrialization and reduced the amount removed by plants through deforestation (EPA, 2006). Therefore, carbon dioxide levels in the atmosphere have grown, leading to a greater greenhouse effect.

Human activity produces carbon dioxide emissions by burning fossil fuels for two primary purposes: transportation and production of electricity. One approach to reduce emissions from electricity generation is to utilize clean sources of energy, such as wind, water, or the sun. Another equally important approach is to reduce the demand for electricity. By reducing demand, the amount of electricity produced may be decreased, resulting in a decrease in carbon dioxide emissions. A way to reduce demand is to improve the efficiency of lights and appliances. Another way to reduce demand is to identify where electricity is used ineffectively. One potential source of wasteful electricity consumption is overnight lighting in non-domestic buildings. Existing data shows that lighting is one of the primary uses of electricity in commercial buildings (Department of Trade and Industry [DTI], 2002). Therefore, minimizing the amount of lighting is one way of reducing carbon dioxide emissions that result from generation of electricity. As there is less need for lighting in commercial offices during the night than during the day, reducing overnight lighting is a logical approach to decrease electricity consumption.

The goal of this project was to develop a methodology for gathering data on overnight lighting in non-domestic buildings and to study the reasons for overnight lighting in the United Kingdom non-domestic building stock. Our sponsor, Carbon Reduction in Buildings (CaRB), will utilize our findings in conducting a broader study of energy consumption in buildings as part of the development of a socio-technical model of carbon dioxide emissions in the UK non-domestic building stock. Refer to Appendix A for a description of CaRB

To accomplish our goal, we developed a series of tasks. The first task was to meet with CaRB researchers to determine exactly what kind of data they needed, as well as to gather additional ideas and resources to use in developing our methodology. Next, we familiarized ourselves with the geographical area of London that we would study by reviewing the layout of buildings as well as existing data on a set of buildings that CaRB provided. For the first few weeks, we observed overnight lighting trends at the street level. After observing at night, we interviewed building managers to gather information that we could not observe from outside and to determine reasons for leaving lights on overnight. Finally, we studied one building from the inside in detail to asses the accuracy of our methodology. Analysis of our collected data resulted in an estimate of energy consumption from overnight lighting and recommendations for further research. With the information gathered over the course of the project, CaRB is one step closer to constructing a carbon dioxide emissions model for the entire United Kingdom.

Background

Global warming is a major issue in international discussion. A scientific consensus exists that the burning of fossil fuels, such as gasoline or natural gas, by humans contributes to an excess of greenhouse gases in the atmosphere. An apparent rise in global temperatures over the course of the last century suggests that human activity, including industrialization and deforestation, is influencing the global environment (EPA, 2006). Historical data show that even slight changes in the average global temperature can cause severe climate change (National Research Council [NRC], 2006). In an effort to minimize humankind's impact on ecosystems worldwide, and to avert a potential global catastrophe, a growing number of nations are taking a hard stance against carbon dioxide emissions and global warming. The United Kingdom is at the forefront of researching greenhouse gas emissions and enacting policies to counter global warming.

A leading approach to combat global warming is the reduction of emissions of carbon dioxide, a greenhouse gas released from combustion reactions. Electricity generation is a major source of carbon dioxide emissions as many power plants run on coal or natural gas (Krackeler et al., 1998). Commercial buildings such as shops and offices consume a great deal of electrical power for lighting (DTI, 2002). However, little is known about energy use in non-domestic buildings (Krackeler et al., 1998). The study of overnight lighting is just one field of research that has emerged from the need to reverse global warming.

Climate Change

The Earth's average global temperature normally fluctuates between periods of warm and periods of cold. These variations of warmer and colder temperatures alternate over long periods due to variations in the Earth's orbit (IPCC, 2001). Other factors may also contribute to changes in the global climate. Variations in the amount of radiation from the sun along with the concentration of greenhouse gases in the Earth's atmosphere affect average global temperature (IPCC, 2001).

Climate data show that relatively small changes in temperature may result in extreme changes in the global environment. According to a report issued by the United States Environmental Protection Agency (2006), average temperature decreased to only 1.1 degrees Centigrade below the average global temperature from previous years during the period known as the Little Ice Age. This event occurred during the 1500s and lasted through the middle of the 1800s. A large amount of evidence, including recorded data on glacier lengths and historical documents, supports the occurrence of this event. Although less severe than other cold periods, the Little Ice Age was still an extreme global condition. According to Scott Mandia (2006), a physical sciences professor at State University of New York (SUNY) Suffolk County Community College, “the colder weather impacted agriculture, health, economics, social strife, emigration, and even art and literature”. More importantly, the event demonstrates that even a small fluctuation in global temperature can result in significant changes in climate.

Recently, the Earth’s average yearly surface temperatures have been increasing. Over the past 125 years, the global average temperature has climbed at a more rapid pace than during other fluctuations in recent history (NRC, 2006). According to the National Research Council (2006), the Earth’s climate has warmed by nearly 0.6 degrees Centigrade during the twentieth century. Figure 1 below illustrates the sharp increase in global temperature over the course of the twentieth century.

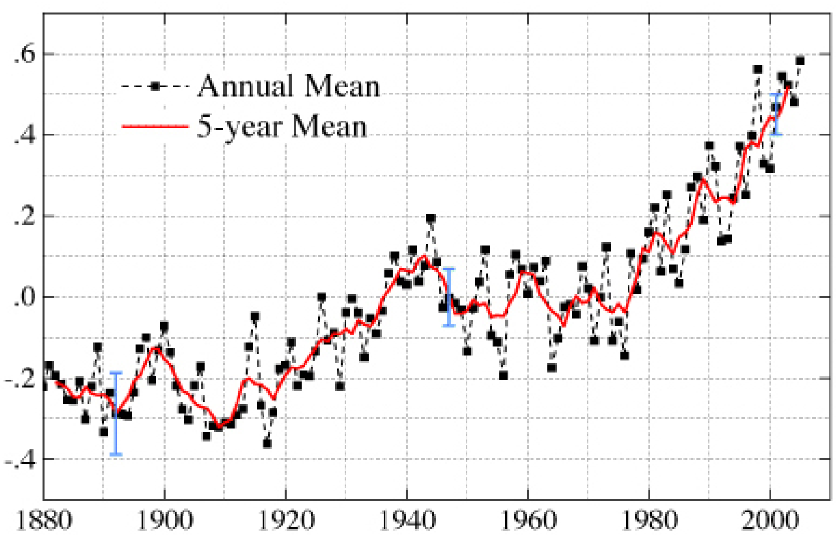

Figure 1: Deviation from Mean Global Temperature (°C) from 1880 to 2000

(Source http://geology.com/news/2006/01/global-warming-graph-and-map.html)

This great magnitude of change represents approximately half of the temperature change that the Earth experienced during the Little Ice Age. Such a change in global temperature is a cause for concern. Both the National Research Council and the Intergovernmental Panel on Climate Change agree that over the course of the next century, the global average temperature will rise another 2 to 6 degrees Centigrade (IPCC, 2001). A worldwide consensus is forming that the Earth is experiencing a period of climate change that is commonly referred to as global warming. This unusually rapid rise in global temperature may result in severe weather and drastic change in climates worldwide.

According to a report by the National Resources Defense Council (2006), a rise in global temperature has the potential to increase drought and wildfire risk, intensify tropical storms and hurricanes, encourage the spread of disease, and cause a drastic rise in sea level. These possible changes may lead to massive changes in the Earth's ecosystems and result in substantial impacts on the global economy.

While regular fluctuations in the Earth's temperature are normal, a growing body of evidence suggests that the most recent rise in global temperature may be the result of human activity. The IPCC (2001) asserts that since the beginning of the Industrial Revolution in the middle of the 1800s, human activity has directly contributed to factors that may lead to climate change. Changes in land use, which have occurred worldwide over the last two centuries, along with increased carbon dioxide emissions from factories are among the most significant causes for an increase in temperatures. In addition, the EPA (2006) notes that changes such as deforestation and urbanization contribute to changes in climate. Changes in the land surface can affect temperature by changing how much solar radiation the land reflects and absorbs. Moreover, industrialization led to the increase of urbanization, which in turn led to greater amounts of fossil fuel consumption as a source of energy (EPA 2006). In addition, deforestation reduces the absorption of carbon dioxide. Experts believe that carbon dioxide emissions make a major contribution to global warming through a process known as the greenhouse effect.

The greenhouse effect results in trapping heat from the sun close to the planet's surface by so-called greenhouse gases in the atmosphere. The atmosphere allows the sun's heat and light to pass through to the Earth's surface. However, the Earth's surface reflects a portion of the heat back into space. Greenhouse gases prevent the excess heat from escaping, which thereby increases the temperature at the surface. The greater the concentration of greenhouse gases in the atmosphere, the less heat can escape. Figure 2 below illustrates this effect.

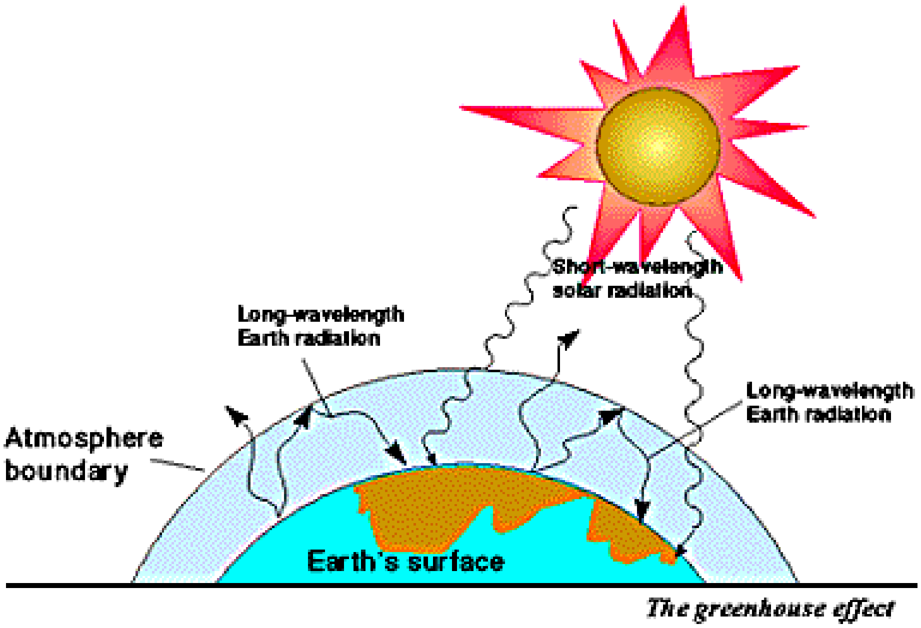

Figure 2: The Greenhouse Effect

(Source http://science.nasa.gov/headlines/y2000/ast20oct_1.htm)

Greenhouse gases, apart from causing potential runaway global warming, are vital for life on the planet. Pieter Tans (2006), a senior scientist at the National Oceanic and Atmospheric Earth System Research Laboratory, stated that "without [the greenhouse effect] our planet would very likely have a frozen surface, akin to that of Mars." It makes sense that an enormous increase in greenhouse gas concentration in the Earth's atmosphere would lead to an overall warming effect, which can be seen in Figure 1. Tans (2006) claims that one percent of the solar radiation absorbed by the Earth's surface since industrialization is due to the greenhouse effect.

Changes in land use also contribute to the amount of greenhouse gases that are absorbed or released into the environment. However, industrialization has affected greenhouse gas concentrations more directly. Intergovernmental Panel on Climate Change (2001) data shows that in the eight hundred years leading up to industrialization, the amount of greenhouse gases in the atmosphere remained remarkably constant, but since then the amount of atmospheric carbon dioxide has increased by over 30 percent. These gases are released into the atmosphere daily by combustion of natural gas and other fossil fuels.

According to the Department of Trade and Industry (2006d), carbon dioxide emissions contribute about 70 percent of the potential global warming effect of anthropogenic emissions of greenhouse gases. Carbon dioxide is not the only greenhouse gas, but it is the prevalent greenhouse gas and accounts for a majority of greenhouse emissions. One of the main causes of greenhouse gas emissions is energy production. Carbon dioxide is produced when fuels that contain carbon are burned to extract energy. Of the three main fuels used in the UK, natural gas produces the least carbon dioxide, followed by oil, and coal produces the most (Pout et al., 1998).

Recently, the DTI (2006c) released its predictions for future carbon dioxide emissions in its report, *The Energy Challenge: Energy Review Report 2006*. The results suggest that UK emissions of carbon dioxide in 2010 will be about 10.6 percent below the level in 1990, or about 9.4 percent away from the domestic goal to reduce carbon dioxide emissions by 20 percent (DTI, 2006c). However, as seen in Table 1, UK carbon dioxide emissions are projected to increase within the next fifty years due to a growing demand for fossil fuels and a growing population.

	Residential sector	Transport sector	Industry	Services	Total CO_2 emissions (including LUC)
1990	40.3	40.0	56.4	23.8	161.4
2000	38.8	41.1	48.9	20.7	143.5
2010	36.7	42.4	45.8	19.5	146.7
2030	41.1	41.5	46.6	21.6	151.4
2050	47.3	40.5	50.3	23.8	162.6

Table 1: Projected UK CO_2 Emissions by sector (Million tons of Carbon)

(Source DTI, 2006c)

Current Efforts to Reduce Carbon Dioxide Emissions

Approximately ten years ago, the threat of global warming reached the international stage. The Kyoto Protocol was created in December of 1997 and entered into force in February of 2005. It was one of the first efforts to limit the emissions of greenhouse gases, specifically carbon dioxide, and to combat global warming. As of December 2006, 165 member nations had ratified the Kyoto Protocol (United Nations Framework Convention on Climate Change [UNFCCC], 2005). While some nations have not signed the agreement, most notably the United States and Australia, the Kyoto Protocol has made global warming an issue of worldwide concern.

Of the 165 nations that ratified the Kyoto Protocol, only 35 were required to reduce their greenhouse gas emissions (UNFCCC, 2005). During the negotiations for the Kyoto Protocol, the developing nations concluded that they would not be required to limit their emissions, since this would adversely affect their economies and also because they had contributed little to the build up of carbon dioxide during the past 200 years. The goal of the Kyoto Protocol was to reduce global greenhouse gas emissions by 5 percent of 1990 levels by 2008-2012 (UNFCCC, 2005). To achieve this goal, each of the 35 required nations was forced to cut its greenhouse gas emissions by certain amounts depending on the levels of greenhouse gases produced by that member nation in 1990 (UNFCCC, 2005).

The mechanisms used to measure greenhouse gas emissions and enforce the Kyoto Protocol are beyond the scope of this project, but it is important to note that member nations may trade "excess" emissions. If the nations reduce their emissions by more than the mandated amount, they may sell the unused percentage to another nation that has produced more emissions than mandated (UNFCCC, 2005). This policy creates incentives to reduce greenhouse gas emissions as much as possible, and allows for a possible profit as well as helping the environment.

Since the protocol's creation, the United Kingdom has become a global leader in enacting policies to reduce carbon dioxide emissions. One idea proposed by the United Kingdom was to implement "green taxes." These green taxes are applied to everyday activities, such as transportation, and are a way to make people pay for using services that emit high amounts of carbon dioxide. An important point to make about green taxes is that they would supplement the current tax system. While all citizens are paying some taxes on income and purchases, only those who pollute more would pay more (Peev, 2006).

Of course, there are many opponents to green taxes. These opponents include citizens fed up with a constant barrage of taxation to those who believe the United Kingdom's approach is fruitless (Cusick, 2006). Such arguments fail to look at the big picture, however. The United Kingdom is striving to become a beacon of change, and to lead by example. By implementing green taxes, it not only begins to help reduce greenhouse gas emissions from the United Kingdom, but it will also demonstrate to the rest of the world how green taxes will work to reduce emissions.

.According to Sir Nicholas Stern, the generated income through green taxes will be invested in reversing carbon dioxide emissions (Her Majesty's Treasury [HMT], 2006). Sir Nicholas Stern, Head of the Government Economics Service in the United Kingdom, completed a document called the Stern Report, which detailed the negative economic impact due to climate change. In the report, Stern suggested a policy that aimed to curb carbon dioxide emissions and avert global warming. Stern concludes that if nothing is done within ten to twenty years, global warming may run out of control and reduce global economic output by up to 20 percent (HMT, 2006).

Likewise, the report states that if governments worldwide impose a one percent tax on the global Gross Domestic Product (GDP), money could be used to slow and eventually halt global warming (HMT, 2006). A one percent levy on the global GDP seems like an unfair imposition on the developing nations of the world. However, Stern mentions this unfairness, and explains that the developed nations must take the lion's share of the burden (HMT, 2006). Policies such as the Kyoto Protocol already attempt to ensure that developed countries have the largest reductions in greenhouse gas emissions.

Another attempt at reducing carbon dioxide emissions is the European Union Emissions Trading Scheme (EU ETS), which is a way of putting a price on carbon dioxide. This scheme creates a strong economic incentive for more energy efficiency and investments that help reduce carbon dioxide emissions (DTI, 2006c). The scheme covers about 11,000 businesses and power stations in the European Union in which each member state has a set allowance of carbon dioxide emissions. Should a company use up its allowance of carbon dioxide emissions, it must purchase excess allowances from another company. The EU ETS places a value on reducing carbon dioxide emissions (DTI, 2006c).

The DTI (2006c) is also attempting to reduce carbon dioxide emissions. They plan to cut the UK's carbon dioxide emissions by 60 percent by 2050, with real progress by 2020. *The Energy Challenge: Energy Review Report 2006*, states the DTI's plan to reduce carbon dioxide emissions. This report states goals, objectives, and plans for reducing carbon dioxide emissions to tackle climate change and to deliver energy at affordable prices for a growing country. Other factors that this report covers are cleaner energy, saving energy, more efficient energy transport, the discussion of renewable energy, and cleaning up fossil fuels.

One of the leading efforts in the UK aimed at facilitating the transition to a low-carbon dioxide economy is the Carbon Vision Partnership. The Carbon Vision Partnership is a collaboration of the Engineering and Physical Sciences Research Council and the Carbon Trust. The Partnership was set up to compile information gained from the carbon dioxide emissions reduction research programs carried out individually by these organizations. The EPSRC (2006) is one of the UK Government's leading funding agency for research and training in engineering and the physical sciences. The Council is currently conducting research with the UK Climates Impact Program and contributing to the Tyndall Centre, which is the national UK center for trans-disciplinary research on climate change (EPSRC, 2006). The Carbon Trust (2006) works with UK businesses to cut carbon dioxide emissions and to develop commercial low carbon technologies.

The largest of the Carbon Vision Partnership programs, Carbon Vision Buildings (CVB), was started in the fall of 2004 to investigate the uses of energy in buildings and their impact on carbon dioxide emissions. The CVB is a four-year, £5.4 million research project to investigate ways to reduce carbon dioxide emissions from the non-domestic building stock. Also, the CVB funds three integrated research projects, Carbon Reduction in Buildings (CaRB), Technology Assessment for Radically Improving the Built Asset Base (TARBASE), and Building Market Transformations (BMT) ("Carbon Vision Buildings Projects," 2006).

Impact of the Non-Domestic Building Stock

The national building stock is a choice target for reducing overall carbon dioxide emissions as buildings consume about half of the nation's energy and are responsible for about half of the carbon emissions (Carbon Vision, 2006). Data from the DTI (2002) shows that in 2001, the domestic and service sectors consumed approximately 44 percent of the total national energy. The service sector involves activities that take place in buildings outside of manufacturing, agriculture, and households, such as schools, hospitals, offices, and commercial shops. According to Krackeler et al. (1998), among the countries in the Organization for Economic and Cooperative Development (OECD), including the UK, the share of electricity use by the service sector rose from 24 percent to 44 percent between 1973 and 1995. The authors explain that the sector consumed more energy as it grew, and carbon dioxide emissions from the sector consequently rose by about 20 percent. Similarly, Hammons and Toh (2001) point out that about 24 percent of all carbon dioxide emissions in the UK come from generating electricity.

Since electricity powers the service sector's primary uses of energy, commercial buildings make a significant contribution to carbon dioxide emissions. Information from the DTI (2006b) shows that in the year 2000 the total amount of carbon dioxide emissions from use of energy by business, or commercial buildings, was 51.5 MtC. Furthermore, the DTI expects carbon dioxide emissions from businesses to increase to 54.0 MtC by 2020. According to

Krackeler et al. (1998), the commercial sector accounts for one-sixth of the carbon dioxide emissions among the OECD countries.

In order to take measures to reduce carbon dioxide emissions from non-domestic buildings, one must have an understanding of energy use in the non-domestic stock. Unfortunately, experience has shown that the study of energy use has proven to be a greater challenge in the commercial sector than in others. Mortimer et al. (1998) cite difficulties in obtaining reliable data on energy use in non-domestic buildings, while Krackeler et al. (1998) point out that end-use data that are available for the service sector are lacking in detail.

Some of the challenges presented by the non-domestic stock include the many different types of buildings as well as an extremely diverse range of activities that consume energy within the buildings. Bruhns, Steadman, and Herring (1997) point out that in relation to the non-domestic stock, the domestic stock is very homogeneous in size, form, and activity. Even one type of non-domestic building in the stock can contain a diversity of activity and size range that is much larger than that of the entire domestic stock. These challenges make it difficult to conduct energy consumption research on non-domestic buildings worldwide. The International Energy Agency (1997) admits that national statistics on energy use in the service sector are often poorly defined. A lack of available complete data prevents a detailed analysis of the specific components that contribute to energy use in non-domestic buildings.

The most extensive research on the UK non-domestic building stock was conducted throughout the 1990s. The project, which is commonly referred to as the Four Towns Study, sought to develop a national non-domestic building stock database, including information on building structure and various forms of energy consumption. Brown et al. (1998) explain that researchers studied the towns of Manchester, Swinden, Tamworth, and Bury St. Edmonds between 1989 and 1992, though most papers on the project emerged later in the decade. The purpose of the project was to provide an abundance of information about as great a variety of non-domestic buildings as possible. Since there exists no national sampling frame from which a sample of the non-domestic stock could be drawn using randomized techniques, researchers sought other ways to ensure that a broad cross-section of the non-domestic stock was observed. The four towns were selected because of their diversity in size and geographical spread in the country. Furthermore, the surveys covered an area that extended from the center of each town to its periphery, so that the study would represent buildings from all sections of each town. Data on non-domestic buildings was obtained from room-by-room inspections of buildings.

Unlike the UK, detailed information regarding non-domestic buildings and their energy use exists in the United States. Mortimer et al. (1998) point to the success of the Commercial Buildings Energy Consumption Survey (CBECS). Conducted since 1979 by the United States Energy Information Administration (EIA), the CBECS was the first national, comprehensive, and statistically representative method of collecting energy-related information with survey techniques. The survey is conducted once every four years, the last occurring in 2003 (http://www.eia.doe.gov/emeu/cbecs/). To gather information about commercial buildings, the EIA first compiles a list of commercial buildings to be surveyed based on specific criteria regarding the size and principal activities of the building. Next, EIA representatives meet with building managers and gather key information including energy use data through personal interviews (EIA, 1998). The study includes a broad range of detailed information and similar studies have been conducted by the EIA to investigate the residential and industrial building stock in the US.

The "Digest of UK Energy Statistics" (DTI, 2006a) points out that the UK non-domestic building stock comprised 18 percent of the total national electricity demand in 2005. Likewise, Krackeler et al. (1998) predict that electricity use in the service sector is likely to increase faster than other energy sources, and state that growth in electricity demand would be a significant cause for increased carbon dioxide emissions. With these points in mind, it makes sense to consider reduction in electricity consumption a key area to address in the effort to reduce these emissions. Krackeler et al. (1998) confirm that reducing electricity use would be beneficial to the UK because of the large amount of carbon-heavy fuels, such as coal, used in power plants. Several key contributing factors to energy use were considered when devising a strategy to reduce electricity use in the service sector.

Among the many activities that consume energy in commercial buildings, lighting is one of the chief end uses. As shown below in Figure 3, lighting represents 15 percent of the UK service sector energy use, second only to heating (DTI, 2002). According to Mortimer et al. (1998), lighting is responsible for 24.75 percent of annual carbon dioxide emissions in office premises. The significance of lighting in the commercial sector is also apparent outside the UK as the US Department of Energy estimates that commercial buildings use 51 percent of the total national energy consumed by lighting in all sectors (US Department of Energy [DOE], 2002). The EIA (1992) estimates lighting to consume 22 percent of all electricity generated in the United States in 1990 and 39 percent of the electricity consumption of commercial buildings.

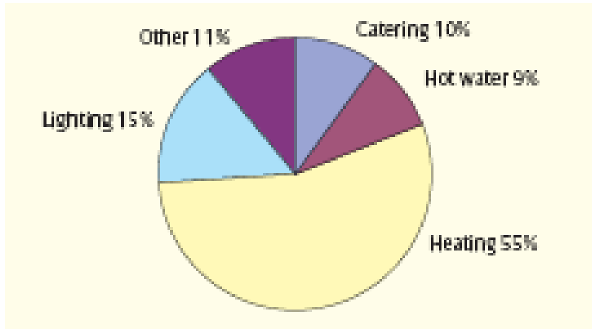

Figure 3: Energy Uses in UK Commercial Sector in 2000
(Source DTI, 2002)

Since lighting represents a significant portion of energy use in the commercial sector, studying the way energy is used in lighting commercial buildings would provide insight into ways to reduce energy demand. Although intensive studies of lighting use, including in the commercial sector, have been conducted in the US, relatively little is known about energy use through lighting in the UK. Outside of the CBECS, there is generally a lack of available detailed information on the non-domestic building stock in other parts of the world, including the United Kingdom. However, the *London Times* published one report of a study on overnight lighting that was conducted in November 2006 by an environmental charity group known as the Global Action Plan (Smith, 2006). The study observed approximately 70,000 windows in 70 buildings along a mile long route in the City of London. Resulting from their study, the researchers concluded that nearly 500 million kWh of energy are wasted each year by leaving lights on overnight in commercial buildings (Global Action Plan, 2006). However, the study did not consider reasons for the overnight lighting neither did it distinguish between energy waste and purposeful uses of lighting.

In an attempt to study carbon dioxide emissions from buildings, the Carbon Vision Partnership, as previously mentioned, created the Carbon Vision Buildings program (Carbon Vision, 2006). The CVB funded CaRB program is conducting a socio-technical, longitudinal study of energy use in buildings and in turn their effect on carbon dioxide emissions. The project aims to fill in the gaps in knowledge regarding energy use in buildings in the UK, especially in the non-domestic stock. CaRB's vision is to develop a public domain model that will predict current carbon dioxide emissions as well as the impact of measures to reduce the emissions. The model will be applicable at the national, regional, city and community level and will incorporate social as well as technical factors affecting energy use (http://www.carb.org.uk).

One of the important factors incorporated into the database is lighting in the non-domestic building stock. In conducting studies on lighting, the researchers track a number of factors that contribute to the total amount of energy used. In both the DOE study, "US Lighting Market Characterization," and the EIA study "Lighting in Commercial Buildings," one of the first steps in gathering data was to define classifications for the buildings that were taken into account in the study (DOE, 2001; EIA, 1992). Commercial buildings were categorized into office, education, medical, etc. In developing a broader database of general energy use in the UK, Mortimer et al. (1998) also established specific categories for different types of buildings. This categorization helped the researchers select relevant target buildings to include in the study. Both studies conducted in the US took advantage of readily available CBECS data to identify, categorize, and tracked specifications of the buildings. Although the CBECS did not track lighting information specifically, the data was relevant in obtaining key information such as floor space and the number of buildings.

The two US lighting studies took different approaches as to how they quantified energy use. The DOE study (DOE, 2002) considered the number of different types of lighting fixtures in various rooms of buildings. However, the EIA study takes a more direct approach in obtaining energy use data by utilizing the equation shown in Figure 4 below (EIA, 1992).

Formal Specification:
The end-use intensity (EUI) can be expressed as the product of the illumination level (brightness), the hours of lighting, and the amount of energy required per unit of illumination. Multiplying the EUI by the floorspace served gives the total lighting energy use for that floorspace. Summing over all floorspace gives total commercial lighting energy consumption.

Thus, the quantities of interest for this analysis are the illuminance **I**, the hours **H** of lighting use, the efficacy Q of the lighting equipment, and the floorspace **S** served by each combination of equipment, illuminance, and usage hours. Formally,

Energy =	**Σ floorspace x**	**hours x**	**illuminance /**	**efficacy**
E (kWh)	**S (ksf)**	**H (h)**	**I (l/sf)**	**Q (l/w)**

where the summation is over portions of commercial floorspace defined by lighting level (illuminance), equipment (efficacy), and usage (hours). The units ksf, h, l/sf, and l/w, respectively, indicate thousand square feet, hours per week, lumens per square foot, and lumens per watt.

Figure 4: Formula for quantifying energy use from lighting employed by EIA
(Source EIA, 1992)

As there is little available information pertaining to non-domestic lighting in the UK, the CaRB project seeks data to include in its socio-technical model of energy use and carbon dioxide emissions. One specific aspect of this problem that this project addresses is quantification of overnight lighting in shops and offices. In order to facilitate this study, we employ methods from similar studies on energy use. CaRB will incorporate the resulting data in their model and future studies. The data and study will contribute to efforts in reducing carbon emissions throughout the United Kingdom.

Methodology

One main goal of this project was to develop a methodology for quantifying energy use from overnight lighting in non-domestic buildings, particularly offices in Bloomsbury, a section of Greater London. CaRB will use the data that we collected as part of a socio-technical model of energy use in buildings in the UK. The project deliverables to CaRB were an estimate of the amount of energy consumed from overnight lighting in non-domestic buildings and the sets of data on overnight lighting.

We accomplished our project goals by meeting the following objectives:

- Establish the data that we must obtain to meet the needs of our sponsor.
- Determine the most appropriate sources for the required data.
- Study the use and waste of overnight lighting in non-domestic buildings to identify and characterize the reasons for energy consumption through overnight lighting.
- Relate the data we obtained on the percentages of illuminated windows to energy consumption and carbon emissions reductions.

To accomplish our objectives, we applied the following strategies:

- Interviewed energy use experts within our sponsor organization to gain knowledge on how they conduct energy use studies in London.
- Met with members of our sponsor organization to establish specific criteria for identifying buildings that were within the scope of the project.
- Selected an area of study in which our sponsor organization had completed previous studies of energy use in non-domestic buildings.
- Made observations of overnight lighting in the selected buildings during the nighttime to verify lighting use and waste.
- Conducted interviews with four building managers to obtain information on building specifications and identify possible reasons for the use of overnight lighting.
- Estimated the amount of energy consumed by overnight lighting and identified potential strategies that may result in the reduction of energy waste through overnight lighting.

Review of Existing Data-Gathering Techniques

In order to establish the specific requirements of our sponsor, we conducted semi-structured interviews with our liaison, Harry Bruhns, and two CaRB researchers, Jorge Caeiro and Hector Altamirano. Through these interviews, we became aware of similar projects that CaRB conducted in the UK, which helped to guide our research approach. One such project was the Windows Air-Conditioning survey, which was a study of the percentages of non-domestic buildings with central air-conditioning systems. This project was helpful because it provided us with a geographical area of study for our research. The study also provided examples of data gathering techniques and surveying strategies. Through meeting with the researchers we established:

- How they picked a geographical area of study and the buildings in the area of study.
- Which geographical area they used in their studies.
- The types of observations they made.
- The methods they employed in gathering data from buildings.
- The requirements our data had to satisfy in order to be useful to the sponsor.
- Which resources from previous studies were available to us, including maps of the geographical area where the studies took place.

In addition to conducting these interviews, we reviewed published works on methods for conducting field work and organizing data. We also finished our archival research by reviewing CaRB's previous data from the Four Towns study and the Windows Air-Con study. From these studies, we obtained information on how CaRB conducted fieldwork and interviews.

Global Action Plan Interview

From meetings with our sponsor, we also learned about an energy conservation charity known as Global Action Plan. This organization conducted a similar study on overnight lighting in office buildings within the city of London in November of 2006. Within their study, they calculated the total amount of energy consumed by the nighttime lighting, as discussed in the Background section of our paper. After we contacted Global Action Plan via e-mail, we set up an interview with one of their team members. From the interview, we were able to compare their methods with our original ideas. We provided minutes from this meeting in Appendix B.

Global Action Plan described the results of its study as an estimation of energy use. To calculate the total energy consumption within the office buildings, the organization's members used a "typical lighting level" for office buildings. The research team obtained this number, which we discuss in more detail in the Discussion section, from the Lighting Industry Federation, and described it as an adequate lighting level for a typical office building. Global Action Plan's methodology also consisted of speaking directly to the City of London to obtain the total amount of office space in the City and using these figures in their calculations. The researchers then used the typical lighting level, the floor space, and the observed percentage of illuminated windows to make an estimate of the amount of lighting per office space. A valuable aspect we learned from this interview was that this study considered all nighttime lighting after 07:00 to be waste. In our study, we attempted to differentiate between lighting waste and use by investigating reasons for overnight lighting, in addition to collecting data on the power consumption that results from overnight lighting.

Area of Study and Building Selection

Discussions with our liaison and other members of CaRB indicated that there was already a pre-defined list of buildings that CaRB observed as part of ongoing studies. In conducting a previous study, CaRB selected a small area of the city that its researchers felt included a typical mix of non-domestic building types in comparison to the rest of London. However, there is no data that determines the extent to which the set of sample buildings is representative of non-domestic buildings throughout London. CaRB's sample of buildings, which was chosen in part because of its close proximity to the CaRB office, lies in Bloomsbury and includes the blocks surrounding University College London. The sample includes 140 office buildings of varying sizes and characteristics. Some of the buildings are large commercial office towers, while others are town houses with only a few floors. While interviewing the CaRB researchers, they provided us with accurate maps of the area of study with target buildings identified by number.

Because the area of study was large and included dozens of city blocks, it was not feasible to collect data on all 140 buildings in a single night. To help solve this problem, we divided the area of study into smaller geographic regions that would require roughly an equal amount of time to catalogue. These regions consisted of either many closely clustered buildings or fewer buildings that required a considerable amount of walking. Using the map provided by our sponsor and shown in Appendix C, we broke the entire area up into nine sections. Each section included a varying number of buildings. By recommendation of our sponsor, we also broke each section up by block letter. These block letters not only aided us in organizing our data, but they will also help our sponsor correlate the data from previous and future studies to the geographical layout of the buildings.

After some initial testing during daytime observations, which we describe below, we determined we were able to canvas roughly half the total area per night. This allowed us to survey the entire area in two nights. We conducted two complete surveys of each half of the total area, resulting in four nights of data. During each nighttime observation, we observed the buildings between 22:00 and 03:00, which were hours during which we believed there would be the least amount of activity within the buildings.

Pilot Study

Before beginning our full survey, we needed to test our original methodology. First, we needed to ensure that we had a camera capable of taking photographs of good quality at night. To accomplish this test, we selected five buildings near the Goodge Street Underground station. We selected these buildings because they included several different structure types and varying numbers of visible façades, and provided ease of access from the Underground station to the area. In addition, we had prior experience with the area from familiarizing ourselves with the main roads in the vicinity of the Windows Air-Conditioning study. These considerations allowed us to have a small but effective test area.

First, we observed buildings during the daytime, which allowed us to take photographs, as well as ensure that we were familiar with the area. This preliminary observation also allowed us to collect contact information, such as business names and phone numbers, from signs on the building exteriors. Next, we observed the buildings on two different nights. Each night we took photographs of the buildings and recorded brief observations. By taking photographs, we were able to quickly obtain data and ensure that we could accurately count the illuminated windows when analyzing the data.

We tested two different digital cameras and discovered each had advantages. While one camera could take better quality photographs, both were adequate. This meant we did not have to depend on one camera and a dead battery or a full memory card would not be a problem. However, we did find that a tripod was necessary for shots at night because the camera's shutter is open longer, which leaves more opportunity for the camera to shake and the photograph to blur. While we originally believed binoculars would also be a useful tool for collecting data, we were able to obtain the same information through the use of the digital cameras. In this respect, the high-resolution camera proved superior, as we could view fine details of the buildings on a computer. In addition to testing the cameras, we tested our data collection sheets to ensure that we were collecting the correct data, rather than collecting information that we could obtain from viewing the photographs.

After completing our pilot study, we made a few changes to the data collection sheets, such as adding more room for comments and removing redundant ways of identifying buildings. Another important addition to the data collection sheet was a column for recording observations of people in the building. The final revision of the data collection sheet appears in Appendix D.

Gathering Building Specifications and Lighting Use Data

We collected data on building specifications and lighting use in two primary ways for the buildings within the target area. First, we observed the buildings from the street level during the daytime and nighttime. Second, we conducted interviews with building managers to obtain information on building specifications and reasons for overnight lighting use.

Daytime Observations

Using the results from our pilot study, we began the daytime observations of our area. After we divided the map into nine sections, as described earlier, we chose sections 1, 2, 3, 4 and 9 to study one day, and sections 5, 6, 7 and 8 to study another day. We group the sections in this way because the first five sections contained a large amount of walking in between a sparse amount of buildings, while the last four sections contained many closely clustered buildings in a smaller area. Thus, we were able to study each group of sections in approximately equal amounts of time.

During our daytime study, we became familiar with the geographical area that we would study again during the night. We photographed each visible façade of every building using a high-resolution digital camera. We also counted the total number of windows each building contained, by either counting the number of windows viewed or analyzing the photographs at a later time. This observation showed us possible issues that could arise during the nighttime study. In addition to photographing the buildings, we also tested the amount of time needed to complete the nighttime study. However, heavy traffic and sidewalk congestion slowed the progress of daytime observations. During these observations we decided that we would only collect data on the office portion of the buildings, and not the shops on the ground floors because of time constraints and the different styles of lighting used in shops. Finally, we found contact information for building managers that we later used to set up interviews.

Nighttime Observations

We completed four nighttime observations, spending two weeknights in one half of the area of study and two weeknights in the second half of the area of study. This method allowed us to view each building at approximately the same time on two different nights. As mentioned above, we used a digital camera to obtain data that we analyzed the next day.

One problem we encountered was how to define a window since the building structures were not consistent. For example, some buildings had a façade entirely made of glass, while other buildings had rows of continuous windows on each floor. To keep observations consistent, as well as to set a standard for future studies, we defined a window as any adjacent panes of glass that the building structure completely surrounds. According to our definition, we did not consider a pane of glass or window frame to be a building structure, thus they do not separate one window from another. The single pane of glass surrounded by building structure on the left side of Figure 5 illustrates our definition of a single window. On the right side of the figure there is a section containing several panes. This large window section on the right is actually four windows, as there are three structural separations between the window sections.

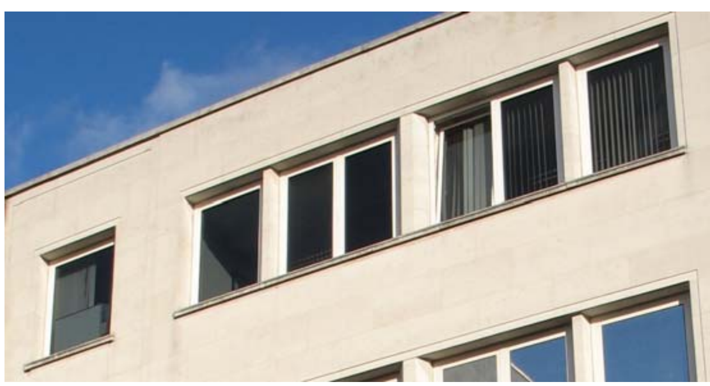

Figure 5: Illustration of Our Definition of a Single Window

During our nighttime observations, partially lit windows, also referred to as light spillage, also became a problem. Partially lit windows occur when light spills from one light source to the remainder of the room. To account for light spillage, we only counted the windows with light emanating from directly behind the window. If we could see a light bulb, or if the light appeared bright enough to be directly behind the window, we would count that as an illuminated window. However, if a window was only partially illuminated, we attributed this to light spillage and would not count this as an illuminated window.

Interviews

Interviews were a source of data that complemented the data gathered from nighttime observations. As described in the daytime observations, we gathered contact information for each building. Since we studied non-domestic buildings, we were able to obtain contact information via the internet, software directories, phone books, and the exteriors of the buildings. We then used this contact information to reach building managers and schedule interviews.

To prepare for the interviews we developed an interview schedule and reviewed surveys provided by CaRB. We compared these surveys to our interview schedule and made any necessary modifications to them. Our interview schedule can be found in Appendix E. We preferred to conduct interviews in person at the buildings of interest; however, we also accepted responses through email. Teams of two members conducted these interviews. One team member performed the interview and asked the questions, while the other team member recorded the dialog. The interviews were semi-structured, lasted approximately ten to fifteen minutes, and provided us with insight into many things that we could not observe from the outside of the buildings. Our interview schedule also left room for discussion to obtain any other relevant information that the contact was willing to offer.

Detailed Nighttime Observation

During our final in-person interview, we arranged a detailed nighttime observation to compare our outdoor observations with what we observed indoors. This detailed observation consisted of going inside the building during the night to observe how the building operated, what type of bulbs are used, how many lights are used at night, and so forth. After conducting the indoor portion of the observation, we then went outdoors to the street level to complete another set of observations by applying our original nighttime methodology. Through this study, we were able to assess whether or not our street level observations were roughly accurate.

We viewed the building at 22:00 on the Monday night prior to our third nighttime observation. Once we arrived inside the building, the security personnel took us to the second floor. There were no people present in the room during the time of the observation; however, we found that all of the lights in the room were on. The room layout was an open plan office with four small offices in one corner. We recorded the total number of lights in the room, as well as the number of illuminated lights, since some of the bulbs were dead at the time. The security guard supplied us with a sample of the light bulb used in the room, which allowed us to determine the number of watts of power it consumes. Subsequently, we were able to calculate the power consumed using the number of lights illuminated, the total floor space of the room, and the wattage of the light bulbs. We present the results of this test in the Results and Discussion chapter.

Compiling and Analyzing Data

We entered data on lighting consumption and building specifications as we obtained them. We defined a data structure to allow our data to be easily integrated into CaRB's existing data on energy use in non-domestic buildings. We developed the data structure into a database for storing and managing information, and used Microsoft Excel to create and manipulate our data. Our collected data consisted of items such as the location, building specifications, lighting use data, and results of interviews with building managers, and is composed of both qualitative and quantitative responses. In addition to organizing the observations, we had over 850 digital photographs that document our day and night observations. We created an organized directory structure to store the photographs and provide an easy way to access the photographs by section, block, and building IDs.

Organization of Data Using Excel

A key step before analysis was to organize and compile data into a database. Our liaison and other CaRB researchers held a workshop for data structuring and analysis. In this workshop, we learned how to divide buildings into sections and how to structure the data that we collected in the field. We became familiar with a method of organizing building data by site, building, slice, and premise. A site refers to multiple buildings that share a characteristic of interest, buildings refer to the physical structures, slices are typically floors that vary significantly in a characteristic of interest, and premises are business that occupy parts of buildings. Because our study only focused on offices, we did not include data from shops on the ground floors. Thus, we did not use sites, or premises, but we excluded slices of ground level shops from the buildings we observed. We noted which portions of each building were included as part of our data.

Once we finished conducting our field work and gathering the necessary information on each building in our area of study, we arranged the data into a data structure using Microsoft Excel. We identified block numbers instead of site IDs since CaRB had not used site IDs in the previous Windows Air-con study. Identifying blocks on the map with ID numbers allows our sponsor to identify exactly where each building is located in each area. We used the same building ID numbers as those used in the Windows Air-Con study, which were provided by our sponsor. In our data structure we broke the building down by floor area, layout type, number of floors, etc. By arranging all the data we received from our field work into this data structure, we were able to manage and analyze our data, as well as incorporate the information CaRB collected as part of its earlier research.

After collecting and inputting our data into Excel, we began analyzing the data. Our analysis determined an estimate of energy consumed by overnight lighting. We used the quantitative data that we gathered along with floor space data from CaRB to produce these estimates. Finally, we analyzed the quantitative data to find patterns in overnight energy use and analyzed the qualitative information to characterize the necessity of overnight lighting in shops and offices.

Organization of Photographs Using Python

To facilitate the analysis of the photographs, we loaded the photographs onto a computer after each observation. Since it was difficult to locate a specific photograph, we created a simple computer program, also known as a script, to organize the photographs. We chose a simple scripting language called Python over other languages such as Perl or C++. Some people describe Python as a "pseudo code," which means it is very easy for someone unfamiliar with the language to read and understand the program. In addition, Python is versatile because it can run on Windows, Linux, and Mac OS X; however, due to limitations in time and experience, our script only runs on Windows. If required, CaRB could modify the script to run on other operating systems without much difficulty. Lastly, Python is an interpretive language, which means that we did not have to time-consuming process of recompiling the code after making changes to it.

Before coding the Python script, we developed an organized structure to store the photographs, shown in Figure 6. This structure needed to be simple to navigate by hand, but also something the Python script could create and traverse. The structure we designed is confusing at first, because we designed for both human and computer interaction. After we had used the structure for about a day, we had no difficulties in navigating and finding specific building photographs.

- Building Photographs
    - Daytime
        - Section ID
            - Block ID
                - Survey ID
                    - Photographs
    - Nighttime
        - Date of Observation
            - Section ID
                - Block ID
                    - Survey ID
                        - Photographs

Figure 6: Visual depiction of the photograph directory structure

One limitation to that the directory structure needs a list of buildings organized by Survey ID, along with Section ID and Block ID displayed. Because our Excel spreadsheets organized the Section, Block, and Survey IDs, we did not encounter a problem compiling this list. It is important to note that the structure is not symmetrical since we conducted our nighttime observations over several nights and needed a way to differentiate between the nights. For our daytime observations, we did not have any reason to segregate photographs by date.

The most important aspect of creating this program was an accurate count of the photographs taken, as well as which façade was in each photograph. It was much easier to input the data and organize the photographs if we meticulously kept track of these parameters while conducting observations. We used the photo tracking sheet, shown in Appendix F, to assist us with this task during our nighttime observations. We found that while the program was helpful, it was still important to keep good records of the photographs we took.

By applying this methodology, we generated a set of quantitative data that allowed us to estimate the power consumption due to overnight lighting and compare overnight lighting patterns among buildings. The considerations we incorporated into our data set will allow CaRB to build on our results and conduct additional analyses of our overnight lighting data.

Results and Discussion

Applying our methodology yielded quantitative and qualitative results. Our project produced a refined methodology for studying overnight lighting, as well as a set of data on overnight lighting in non-domestic buildings in a particular geographical area. Another result of the project was a set of photographs of each sample building in our area of study. We summarize the data that we obtained as part of the study in the Results section. The Discussion section outlines the analysis of the quantitative and qualitative results produced by our applied methodology.

Results

We obtained data for our study from three main sources. One source was a pilot study to test our methods and obtain preliminary overnight lighting data. Another source of data was each of the four overnight observations along with the detailed observation of a building. The third source was the four interviews we conducted with building managers. This section presents the results from each of these data sources.

Results of the Pilot Study

We summarize the data from our pilot study observations in Appendix H. While we found slightly different patterns of illuminated windows on each night, the average percentage of illuminated windows was similar on both nights. As a result, we found approximately 47 percent of the windows illuminated on the first night and 54 percent on the second night. Our field notes provided additional information about lighting in these buildings. In Building 25 (all buildings will be denoted by their survey identification numbers), for example, we found that the stairwell was illuminated on one night and not the other. In Building 23, we observed all the lights on the second floor switch off simultaneously, which indicated that the building layout was open plan and that likely all the lights are controlled by a single switch. We created a simple data structure to organize these findings. However, we did not perform extensive analysis on these preliminary data, as the focus of the pilot study was to refine the methodology.

The pilot study gave us the opportunity to try our methodology in the field and deal with only a small amount of data to start. This preliminary fieldwork demonstrated that taking photos is an efficient way to record information about each building. Based on the results of these observations, we updated our methodology to work out problems we encountered. Most importantly, the pilot study demonstrated that our methodology allowed us to obtain data on overnight lighting in non-domestic buildings. With a test of the methodology completed, we proceeded to collect data for the full study. We discuss resulting updates to the methodology in the Methodology chapter.

Quantitative Results

A primary purpose for the street-level observations was to collect quantifiable data from which we could estimate the amount of energy consumed by overnight lighting in our set of non-domestic buildings. We achieved this estimate by counting the number of illuminated windows that were on the façades of each building in our set. This calculation involved data from daytime and nighttime observations. Additionally, we obtained physical characteristics of the building, such as the total number of windows, from the daytime observations. The nighttime observations provided us with the number of illuminated windows. Our photographs of the buildings served as a record of the number of illuminated windows at the time we observed the building. As we observed building features in each photograph, we populated our data structure with quantitative data.

We created our data structure as a series of Microsoft Excel spreadsheets. Each spreadsheet contains a different set of information about our buildings. On every spreadsheet, a survey ID number specifies to which building each piece of data corresponds. Every building has a unique survey ID number. The data structure contains spreadsheets that store building identification information, physical characteristics of buildings, data from each nighttime observation, and analysis of data from each nighttime observation. We present the information from our data structure in the tables in appendices I through N.

Appendices I through L provide data that support our overnight lighting research. Appendix I has information about the location of each building. The appendix contains the street name, street address, and house name, if available, for each building. The first column in the table, Building ID, gives a unique identifier for each building that CaRB uses to keep track of data on this set of buildings. We maintained this identifier so that CaRB can combine our data with their existing data. The next three columns, Survey ID, Section, and Block, are common to all tables that provide data on individual buildings. We used the Survey ID to identify to which building each piece of data corresponds, as this identifier appears on the map in Appendix C. The

Section and Block columns provide the geographical locations of the buildings in our area of study.

Appendix J provides data on the physical characteristics of the buildings. Again, we present the Survey ID, Section, and Block for each building. The rest of the table specifies the total number of floors, the area per floor, the total area of each building, the floor space category, as well as whether the building is known to have central air conditioning. We obtained the total number of floors from our daytime observations of each building. The area per floor and air conditioning information were existing CaRB data that we were able to incorporate into our research by using the building ID numbers. The total area is the product of the area per floor and the number of floors in each building. CaRB provided us with the building size classifications that we employed in Appendix J. The classifications are 0-100 m^2, 101-300 m^2, 301-1000 m^2, 1001-3000 m^2, 3001-10000 m^2, 10001-30000 m^2, and 30000+ m^2. H. Bruhns (personal communication, February 16, 2007) noted that CaRB uses these same classifications as part of its modeling of energy use in buildings. We provide a comparison of overnight lighting in buildings of different size in the Discussion section.

Appendices K and L present our collected data from our daytime observations. Appendix K specifies the floors of each building that we considered in our study, the number of floors that we considered, and the floor space that incorporated into our power consumption estimates. Since our study dealt only with overnight lighting in office buildings, we needed a way to exclude with the ground level shops that are common in many office buildings in our area of study. In cases where there was a store on the ground level of a building, we did not count the windows on the ground floor. The Included Floors column in Appendix K specifies the floors that we considered for each building, while the Counted Floors gives the number of floors that we included. The Included Floor Space is the product of Counted Floors and the Area per Floor, and it provides the floor space of the part of each building that we considered in our study. Appendix L presents the data on the number of windows in each building. In the Windows per Façade column, we listed the number of windows that we counted on each façade of every building. If we were able to see a façade, we indicate the number of windows in the column that specifies which cardinal direction the façade faces. The blank fields indicate that there is no building façade in that direction, or that it was not visible to us from the street level. The Total Windows column on Appendix L provides the sum of the number of windows on each façade, which we considered the total number of windows in each building. The Visible Façades column specifies the number of façades that we were able to see.

Appendix M provides Quantitative Data from our nighttime observations. Each table in this appendix provides data on the number of illuminated windows from each night that we conducted an observation. We specify the number of illuminated windows that we observed on each façade in a manner similar to the table in Appendix L. For each façade, we indicate the number of illuminated windows. In cases where we observed zero illuminated windows on a façade, we put a zero in the table. The Total Illuminated Windows column is a sum of the number of illuminated windows for each building. Lastly, the Time column specifies the time at which we observed the building at night.

Appendix N provides our estimates of power consumption from lighting at the time we observed each building. We presented the power consumption estimates in four tables, each corresponding to the nighttime observation from which the data originated. In Appendix N, the data tables provide the percentage of illuminated windows at the time of the observation. Additionally, the tables also provide the floor space in each building that we estimated to be illuminated. The illuminated floor space is the product of the area per floor from Appendix J and the counted floors from Appendix K. The power consumption is a product of the illuminated floor space and a power density of 12.5 W/m^2. We discuss the significance of this figure in the Discussion section.

Finally, Appendix O provides the results of our detailed observation. The appendix includes the notes from the observation as well as our assessment of the quantitative results of our applied methodology for estimating power consumption. In this appendix, we present the calculations by which we determined the error in the quantitative results of our methodology.

Qualitative Results

In addition to collecting data to quantify the power consumed by overnight lighting in office buildings, we also collected qualitative data in the form of interview responses from building managers. While we attempted to contact people in approximately three-fourths of the buildings we studied, only four building managers agreed to provide any information. We were able to conduct three interviews in person and one building manager provided responses to our questions over email. We present the results of the four building manager interviews that we conducted in Appendix P. We did not include the names of the building managers we interviewed in this report to preserve confidentiality. Additionally, we made qualitative observations regarding potential uses of overnight lighting while collecting data in the field. Appendix Q presents field notes from instances where we observed people present in buildings during our nighttime observations along with the number of times we noted an illuminated stairwell during each observation.

Discussion

The results of our applied methodology provided us with a means to estimate the power consumed by overnight lighting and make comparisons of overnight lighting among buildings. Additionally, as a refined methodology for quantifying overnight lighting is a result of the project, we evaluated the methods we used to gather our data with a detailed observation of one building that we could access at night. Finally, the qualitative data we gathered while conducting the study provide some insight into practices that result in use and waste of energy through overnight lighting.

Quantitative Results and Power Consumption Estimates

The quantitative results that we gathered are one product of our applied methodology. We gathered data in the form of total and illuminated windows per façade on each building. From these raw data, we determined the percentages of illuminated windows for each building. These results effectively quantify overnight lighting in office buildings. Percentages of illuminated windows in each building provide a measure of overnight lighting that is common to all buildings we observed. Thus, the percentages allow us to compare overnight lighting among the buildings.

From the percentages of illuminated windows we compiled an estimate of the power consumed by overnight lighting in all the buildings. As the process of generating the power that is necessary to illuminate buildings at night creates carbon emissions, our estimates of power consumption are a relative gage of the impact of overnight lighting on carbon dioxide emissions in each building. We used the equation presented in Figure 7 to estimate power consumption per building.

$$\text{Power consumption (kW)} = (\text{Illuminated windows} / \text{Total windows}) \times (\text{Included floor space}) \times (12.5\ \text{W/m}^2) \times (1\ \text{kW} / 1000\ \text{W})$$

Figure 7: Equation for Estimate of Power Consumption from Overnight Lighting

The equation incorporates data from Appendices I, J, K, L, and M. We provide the results of applying this equation to data from each building in Appendix N. To estimate power consumption, we multiplied the fraction of illuminated windows over total windows by the included floor space in each building. This product is an approximation of the amount of floor space in the building that is illuminated. As part of our analysis, we made the assumption that in each building, the fraction of windows that were illuminated corresponds to the floor space in the entire building that was illuminated.

Next, we correlated the amount of illuminated floor space in each building to the amount of power that is necessary to illuminate the floor space by multiplying by a power density of 12.5 W/m^2. We originally obtained this figure through our interview with Global Action Plan. We consulted with University College of London lighting expert P. Rayham (personal communication, February 1, 2007), who indicated that the figure is "a bit above a best practice" for lighting a typical office space. He noted that the figure is reasonable and we would likely encounter this power density in practice as energy targets are often missed. We referred to commercial lighting energy targets from the Society of Light and Lighting, which can be found in Appendix R. The code provides a target of 11 W/m^2 for an average office with a typical level of lighting, which Mr. Rayham (personal communication, February 1, 2007) indicated would be a bit low for power densities that are found in practice (Society of Light and Lighting, 2006). Thus, we decided to employ the reasonable power density of 12.5 W/m^2 as a way to correlate our estimates of illuminated floor space to power consumed by lighting in each building. One limitation of our methodology was that we could not determine how much of the floor space actually was office space. Therefore, we used the same assumed power density for all the included floor space of each building, which included lobbies and stairwells with windows. As the final step in estimating power consumption, we converted the power estimate to kW as the last part of the equation in Figure 7.

Table 2 summarizes the quantitative results of our nighttime observations. The table presents the average percent of illuminated windows in all the buildings that we observed on each night. Likewise, the table also shows a total of the power consumption estimates of all the buildings that we observed during each observation. The total power consumption is a measure of how much power overnight lighting was consuming among all the buildings we observed on each night.

We observed 62 buildings in sections 1, 2, 3, 4, and 9 on night 1 and again on night 2, and we observed 78 buildings in sections 5, 6, 7, and 8 on night 3 and again on night 4. Since the data came from separate sets of buildings, Table 2 presents the results of the observations from nights 1 and 2 separately from the observations from nights 3 and 4.

Night	Average Percent Illuminated Windows	Total Power Consumption
1	24.8%	571 kW
2	15.3%	416 kW
3	18.4%	390 kW
4	17.2%	322 kW

Table 2: Summary of Quantitative Results

In addition to the fact that the data was gathered from different sets of buildings in our area of study, the data summarized in Table 2 also varies in terms of when it was gathered. We conducted the night 1 and 2 observations on Monday nights, while the night 3 and 4 observations took place on a Thursday night and Monday night, respectively. One interesting note about this summary of the data is that the average percent illuminated windows showed less variation in data from nights 3 and 4 than in data from nights 1 and 2, as the latter observations were conducted on the same night of the week. The percentages of illuminated windows for each building allowed us to quantify overnight lighting and make comparisons to find whether overnight lighting is more common in certain buildings than in others.

Patterns in Overnight Lighting

Since we observed each of the 140 buildings twice, we have a total of 280 observations of buildings that comprise our quantitative data. We found that the average percentage of illuminated windows among all the observations was 18.9 percent. Similarly, we estimated the average total power consumption for all the buildings in our area of study to be 850 kW. This figure represents the sum of the averages of the total power consumption from the first two and last two nights of observations. In addition to estimating the power consumed by overnight lighting from our data, we made several analyses of overnight lighting in office buildings by comparing the percentages of illuminated windows.

Figure 8 provides a frequency distribution of illuminated windows from all our observations. The chart shows that we observed 91 buildings with no illuminated windows, which is approximately one-third of all our observations. Of the 189 observations where buildings had illuminated windows, most of the buildings had 20 percent or fewer illuminated windows. We observed buildings with 10 percent of fewer illuminated windows 44 times and buildings with 11-20 percent illuminated windows 46 times. Furthermore, we only observed 22 buildings that had more than 50 percent of illuminated windows, and we noted buildings with all windows illuminated six times.

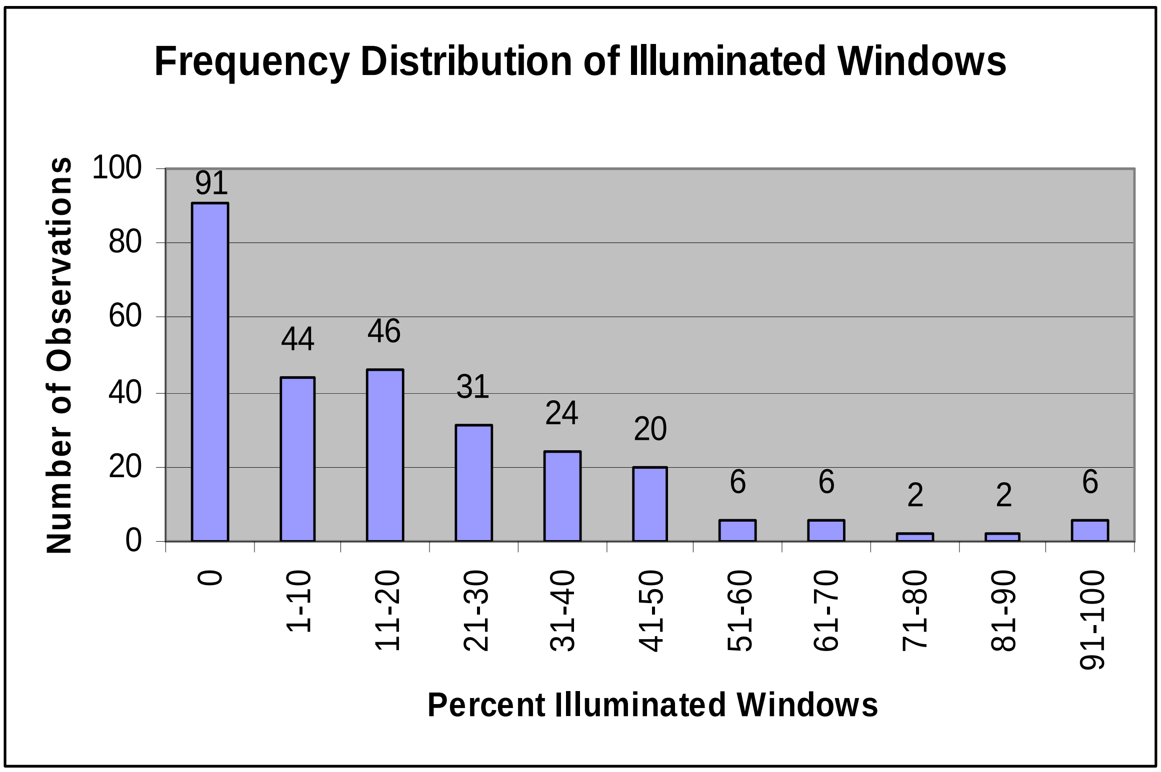

Figure 8: Frequency Distribution of Illuminated Windows

We compared overnight lighting in buildings of different sizes to see whether buildings of particular sizes tend to leave more or fewer lights on overnight. We used total floor space as a common measure of size among all the buildings. Table 3 provides a summary of observed overnight lighting in terms of the building size categories. While average percent of illuminated windows does not vary greatly among most of the categories, Table 3 shows that the percent of times we observed a building with zero illuminated windows decreases with each category of increasing building size. This pattern suggests that bigger buildings are more likely to have lights on overnight than small buildings, but we cannot assert that this pattern occurs in office buildings outside of our sample.

Our results indicate that sample buildings in the three categories with greatest floor space have a higher average percentage of illuminated windows than buildings in the two categories of less floor space. However, the median percent of illuminated windows suggests that the average percent in the two smallest size categories is skewed due to the large number of buildings that had no illuminated windows. The mean and median percentages of illuminated windows are close for buildings in the largest category, indicating that this average is not skewed by extreme data points. While the largest category of buildings has the highest average percentage of illuminated windows, our set of sample buildings included only three buildings in this category. Therefore, the result may not be representative of other buildings.

Table 3 also shows the average power consumed by overnight lighting in all the buildings in each category. While there appears to be significant differences in the amounts of power consumed among the categories, the average power consumption increases with the increasing floor space of the buildings in each category. Simply stated, more light bulbs are necessary to illuminate a large floor space than a small one, which results in a greater power consumption in large buildings. Additionally, the high number of buildings with no illuminated windows in the smaller size categories skews the average power consumption estimate to suggest a lower power consumption than the actual figure. Therefore, it is likely that there is not quite as much variation between average power consumption in buildings from smaller and larger size categories.

Building Size (Total Floor Space)	Average Percent Illuminated Windows	Median Percent Illuminated Windows	Observed Zero Illuminated Windows	Average Power Consumption	Number of Buildings in Category
101-300 m^2	17.4%	0.00%	64.3%	0.32 kW	7
301-1,000 m^2	8.41%	0.00%	59.5%	0.65 kW	37
1,001-3,000 m^2	24.3%	16.5%	25.0%	4.79 kW	56
3,001-10,000 m^2	20.3%	16.2%	13.5%	11.4 kW	37
10,001-30,000 m^2	29.1%	28.0%	0.00%	45.1 kW	3

Table 3: Comparison of Buildings by Size

Figure 9 presents the total floor space and percent illuminated windows of each building observation in a scatter plot. As we have an approximate bell-shaped distribution of buildings among the exponentially-increasing size ranges, we arranged the data points on semi-logarithmic axes to show the percentage of illuminated windows in relation to floor space. The scatter plot shows that most of the data points with more than 50 percent of illuminated windows occurred between total floor space of 500 m^2 and 5,000 m^2. Overall, most of the data points are concentrated below 50 percent of illuminated windows across the whole range of total floor space.

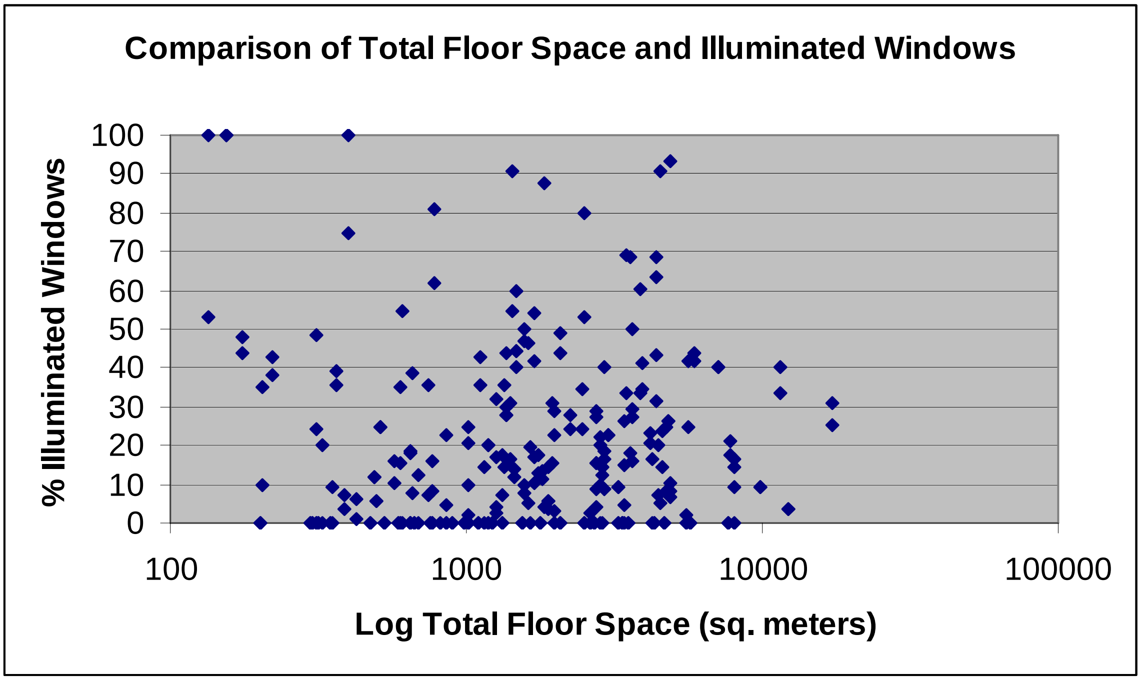

Figure 9: Scatter Plot of Floor Space and Percent Illuminated Windows

We noted the time of night as we observed each building during the nighttime observations. Table 4 presents the average percent of illuminated windows in each hour during which we conducted nighttime observations. All our observations took place after 22:00. We conducted only four observations after 03:00, which we included in with the after 02:00 category in Table 4. The table shows that we found the highest rates of illuminated windows during the first hour of conducting observations, and the fewest during the last hour. However, we observed each building twice following approximately the same route during each observation, and both observations of each building usually occurred within one hour of each other on different nights. Therefore, the average percentages of illuminated windows on Table 4 represent data from most of the same buildings for each hour, and they may not entirely reflect whether more lights are turned off later in the night. For example, we observed Building 30 at 00:07 on the first night and 01:51 on the second night and we found approximately 15percent of the windows illuminated during both observations. Conversely, we observed Building 5 at 22:54 on the first night and found 93.5 percent of illuminated windows, and we observed the building at 00:28 on the second night and found 8.06 percent of illuminated windows. Therefore, we observed cases where there is significantly less lighting as well as the same amount of lighting in buildings at different times during the night.

Time of Night	Average % Illuminated Windows	Number of Observations
22:00-22:59	26.8%	40
23:00-23:59	16.8%	97
00:00-00:59	19.4%	79
01:00-01:59	17.4%	34
after 02:00	14.2%	30

Table 4: Illuminated Windows by Time of Night

One goal of our project was to generate overnight lighting data that is compatible with existing CaRB data, specifically data from the recent Windows Air-Conditioning study. By using the same building identifiers as in the previous study, we correlated our overnight lighting data to the existing air-conditioning data. The result is a comparison of percentages of illuminated windows by buildings with different kinds of central air conditioning systems. We present these data in Table 5. The table suggests that buildings with central air conditioning systems in our area of study tend to have higher rates of illuminated windows at night than buildings without central air conditioning.

Central Air Conditioning	Average Percent of Illuminated Windows	Number of Buildings
Both Diffusers & Cassettes	45.9%	2
Cassettes	23.4%	23
Diffusers	20.1%	31
None	16.9%	32
Not Identified	16.1%	52

Table 5: Comparison of Overnight Lighting in Buildings with Air Conditioning

Finally, CaRB researchers expressed an interest in the comparison of percentages of illuminated windows by street to form an idea of whether buildings on main roads tend to have higher rates of illuminated windows than other streets. We were able to make this correlation in our data as CaRB provided us with the street address of each building in the area of study. We categorized the buildings by their address, even if they had façades on more than one street. Figure 10 provides the average percent of illuminated windows for each street on which we had two or more buildings; the number of buildings on the street appears in parentheses after the street name. While Conway Street appears to have the highest rates of illuminated windows, the street had only two sample buildings; in fact Conway Street was one of the smallest back streets in our study. Charlotte Street, Tottenham Court Road , and Whitfield Street each have approximately the same number of sample buildings. While Tottenham Court Road is the largest and busiest of the three, it had lower rates of illuminated windows. This notion suggests that buildings on busy streets do not leave more lights on at night than buildings in side streets in this particular geographical. The great variation in the number of buildings on each street, however, prevents a conclusive comparison of rates of illuminated windows by street.

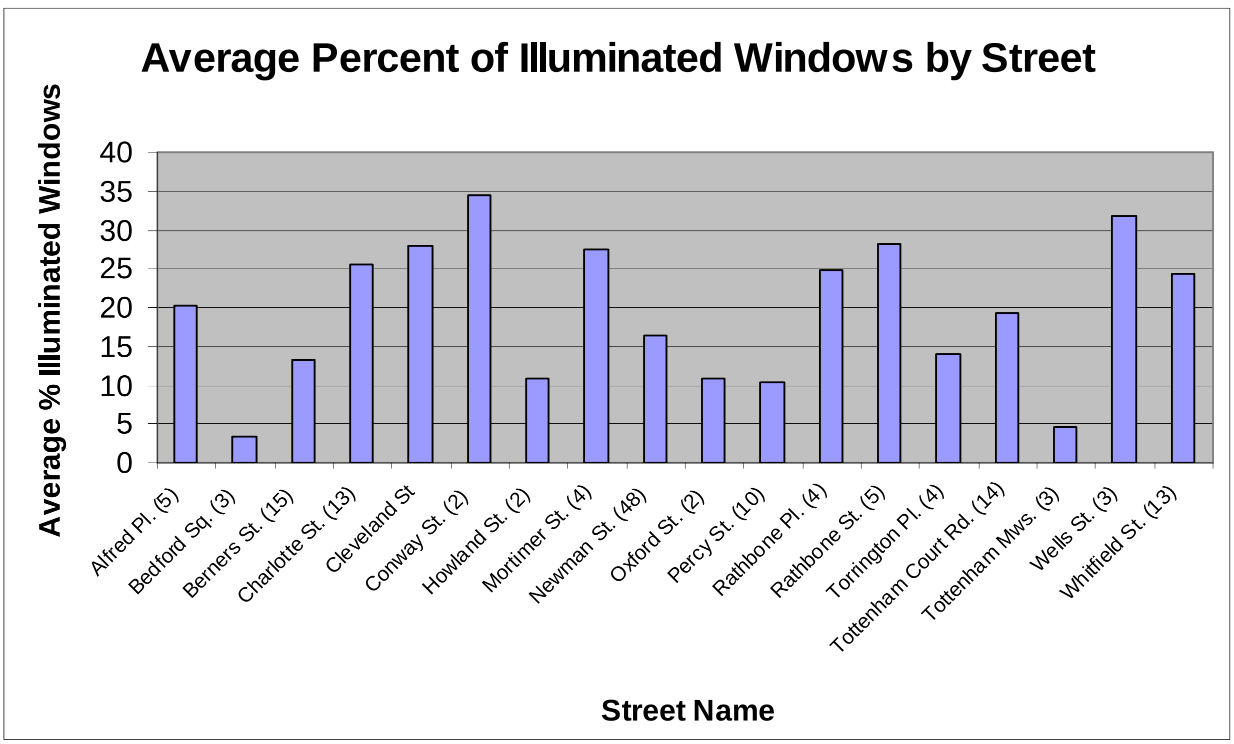

Figure 10: Comparison of Overnight Lighting by Street

While we systematically gathered data from our set of non-domestic buildings according to our methodology, we cannot assert that our quantitative results can be extrapolated to the entire non-domestic stock. Although CaRB indicated that the buildings we observed were typical in terms of size and mix, they are not necessarily representative of buildings in other parts of London. To the extent that this sample of buildings is representative of the non-domestic stock throughout the city, the energy use estimates and patterns in overnight lighting can be generalized to other buildings in other geographical areas. Our results provide CaRB researchers with a general idea of patterns in overnight lighting that they may find if they continue the research. We designed our study to serve as a pilot to test the methodology and gather preliminary data for a more extensive study of overnight lighting in non-domestic buildings.

Comments on Applied Methods of Gathering Data

One of the goals of the project was to develop a methodology for gathering data on overnight lighting in non-domestic buildings. Street-level observations proved to be an efficient way to gather lighting data on many buildings in a short amount of time. The method allowed us to obtain quantifiable results with which we could compare overnight lighting among buildings. Additionally, the photographs of building façades that we took as part of implementing our methodology provided a record of overnight lighting in the building at the time we observed it, and allowed us to verify our results after the observation.

Analysis of the quantitative data allowed us to estimate the amount of energy consumed by overnight lighting in our set of office buildings. However, the outside observations provided limited amounts of detail as to how many lights were on in parts of buildings that were not immediately next to the windows. This limitation forced us to assume that the percentage of illuminated windows corresponds to the percentage of illuminated floor space, as we had no way to measure the actual amount of illuminated floor space in each building. Having such a measure would have yielded results of greater accuracy, as we are more concerned with comparing the percentages of illuminated floor space among buildings than the percentages of illuminated windows. In our study, we assumed both percentages to be the same.

The limitations of our methodology for gathering data also stem from a lack of available information about the layout of each building. As the only floor space data available to us was the area per floor, we treated the entirety of every floor as office space. Our data did not reflect any stairwells or lobbies that we observed, as we had no way to tell what amount of floor space these parts of buildings occupied. These simplifications likely affected the accuracy of our energy consumption estimates as we applied the power density of a typical office for all the illuminated floor space. During our nighttime observations, we observed that office spaces usually have fluorescent bulbs evenly spread out throughout the office. However, lobbies tend to employ different types of lights arranged less consistently than office spaces. Furthermore, we found that stairwells tend to be darker than offices. P. Rayham (personal communication, February 9, 2007) indicated that a power density of 5 W/m^2 would be reasonable for stairwells, as opposed to the 12.5 W/m^2 that is found in office spaces. Since we used the power density of offices for all illuminated floor space without differentiating lobbies or stairwells, a potential source of error exists in our power consumption estimates.

While we are not entirely certain of the error in our results, we attempted to gage the overall accuracy of our method of estimating power consumption during our detailed observation. Appendix O provides a detailed account of the detailed observation. The appendix also shows the calculations by which we compared the results of an accurate measurement of power consumption in the building and a typical estimate of power consumption based on data from an outside observation conducted according to our methodology. As a result of this comparison, we found the error in the estimated power consumption of only the office space in the building to be 5.18 percent. A comparison of estimated power consumption for the entire building resulted in an error of 10.9 percent. However, this comparison included an estimate of power consumption in the lobby and a stairwell, which was based on the best available data.

As we conducted one test to assess the accuracy of the methodology in one building as part of our study, additional tests can further refine the estimates. Extensive testing of the methodology in several different buildings where the exact power consumption is known for all parts of the building would provide more information as to the accuracy of our power consumption estimates. While our detailed observation gave us an idea of the accuracy of our methodology in one situation, we cannot assess the accuracy of the quantitative results from all the buildings we observed.

Use and Waste of Overnight Lighting

In addition to gathering quantitative data to compare overnight lighting among buildings, we also collected data to investigate reasons for practices that result in overnight lighting in non-domestic buildings. The responses to the four building manager interviews we conducted, along with our observations from the field, compose this portion of our data. As part of our project, we sought to establish reasons why people leave lights on overnight and differentiate between useful and wasteful applications of overnight lighting.

We observed illuminated windows in approximately two-thirds of our building observations. Responses to our interview questions provided us with information as to why lights are left on in these buildings. However, the four building managers who agreed to interview with us are a self-selected sample that is not necessarily representative of the entire target population. While the building managers' replies provided useful information, we cannot assert that these replies reflect the views of all building managers. The building managers who agreed to respond to our interview may exhibit a bias in favor of environmentally friendly practices. As such, the overnight lighting practices that these managers employ may not reflect the practices of building managers with different views on energy conservation. Nonetheless, we found the replies helpful in explaining some reasons for overnight lighting in offices.

The replies to our interview questions indicate that practices of turning lights off at night vary among buildings. In this discussion, we refer to each building manager according to the order in which the corresponding interview appears in Appendix P (e.g. the interview subject of Interview 1 is Building Manager 1). Building Manager 3 indicated that he sweeps the building before leaving to make sure that all unnecessary lights are turned off. He also maintains logs of when employees leave and whether they turned the lights off, as well as sends group emails to employees reminding them to turn their lights off. The remaining three building managers do not take such extensive measures to reduce overnight lighting. Building Manager 4 replied that employees are asked to turn lights off if they are the last to leave the office, while Building Manager 1 indicated that the cleaners are responsible for turning off lights in offices when they leave in the evening. Lastly, Building Manager 2 stated that employees simply turn lights off by habit when they leave. Although these practices were different, all the building managers seemed aware that leaving unnecessary lights on at night is a waste of energy and recognized the importance of minimizing overnight lighting.

While the building managers appear to try to reduce overnight lighting, they also provided some reasons as to why lights may be left on overnight. Only Building Manager 2 indicated that there is no need to have lights left on in the building overnight. The responses of the other managers; however, show that they leave some lights on intentionally for purposes they consider useful. Building Manager 3 stated that he turns off unnecessary lights during his evening sweeps of the building. The statement suggests that he leaves some necessary lights turned on overnight. Building Manager 4 indicated that the reception is the only part of the building that remains illuminated, while it is not required that lights should remain on in any other part of the building. Security is likely an important reason for leaving the reception area or main entrance of a building illuminated, as an intruder may attempt to enter the building this way. Building Manager 1 specifically referred to security as a reason for leaving parts of a building illuminated. He stated that security cameras, which are located by the main entrance and in hallways, do not work properly if the area they are monitoring is not illuminated. Safety and security are sound reasons why building managers would intentionally illuminate access ways, such as hallways and stairwells, at night. This notion is consistent with the qualitative data from our field observations. We observed illuminated stairwells in about one-fourth of the buildings that had any illuminated windows, shown in the field data presented in Appendix Q. However, we cannot assert that the reason all these stairwells were illuminated was safety and security, as only one building manager indicated that these are the reasons he leaves access ways illuminated. Conversely, the night manager of the building in which we conducted the detailed observation noted that he turns off the lights in the stairwells when there are no employees working in the offices, suggesting that building managers can minimize the amount of time that stairwells are illuminated.

Another useful purpose of overnight lighting in office buildings is to illuminate the workspace for employees who are working late. Three of the building managers stated that employees work typical business hours, but they may stay to work late. These building managers indicated that the lights are typically turned off for the night and turned on again in the morning when cleaners and employees begin arriving. Building Manager 3; however, indicated that his company operates twenty-four hours per day, and therefore some of the office space must remain illuminated through the night. Furthermore, we observed people working in buildings on several occasions, as specified in Appendix Q.

While the responses of our building managers suggest that there are useful applications of overnight lighting, we also found that waste occurs when lights are left on overnight without serving any purpose. Building Manager 1 stated that negligence, or employees simply forgetting to turn the lights off, is a reason why unnecessary lights are left on in the offices. Building Manager 3's practice of sending reminders suggests that employees in his building also forget to turn lights off. The operation of light switches may be another cause of waste through unnecessary overnight lighting. If only one employee is working at his desk, then it seems excessive to completely illuminate an entire open plan office. However, in some buildings there is only one switch to control all the lights in a large office. On several occasions, we noted all the lights turn on or off simultaneously on an entire floor of a building, which suggests that they were all controlled by one switch. Two of the building managers stated that there are several switches that control the lights in the offices, while one building manager stated that one switch controls all the lights in the room. Building Manager 3 indicated that he turns off about 70% of the lights if he encounters only a few people working in a large office. Illuminating only necessary portions of large offices is a way to minimize the waste of energy through overnight lighting.

The qualitative data we gathered as part of our study provided insights into reasons for leaving lights on overnight in office buildings. We discovered that there are useful and necessary applications of overnight lighting, but some practices result in waste when lights are unnecessarily left on. As we did not know exactly why lights were left on in each building that we observed, it was impossible to determine from our data an exact figure for the amount of energy wasted due to overnight lighting in our sample buildings. While we noted completely illuminated yet seemingly empty office buildings, we can only infer that the lights were left on without serving any apparently useful purpose. The results we presented outline practices of overnight lighting, which may occur in some office buildings within and beyond our set of sample buildings.

Conclusions

Many non-domestic buildings remain illuminated through the night.

We observed that lights were left on overnight in approximately two-thirds of our building observations. In most cases, only parts of each building were illuminated when we observed it. However, lights were on at a time when one typically does not expect to find people present who would require the building to be illuminated. We found the practice of leaving lights on overnight to occur in buildings of various sizes, in buildings on main roads as well as those on back streets, and at all times of the night during which we conducted our observations. From our data alone, we cannot be certain as to how closely the rates of illuminated buildings that we found in our sample correspond to rates from buildings in other areas of London. However, the consistency with which we observed lights left on in office buildings suggests that the practice is widespread. Since leaving lights in offices at times when there are few or no people present appears commonplace, there exists the potential for a great amount of energy that could be conserved. A more extensive study of overnight lighting may produce results that indicate the extent of this energy conservation and specify in which buildings employees could make the greatest impact by evaluating their practices of overnight lighting.

Overnight lighting serves useful purposes, but an excess is a waste of energy.

Our results show that there are in fact reasonable and necessary uses for leaving lights on in office buildings at night. While people may not be present in a building to require lighting at a particular moment, leaving lights on in access ways allows a person who may arrive at the building to find his way around safely. Similarly, leaving lights on in access ways can make an intruder visible to a security guard or camera. In some cases, people require an office to be illuminated as they may work late into the night. In such cases where lights are left on intentionally to fulfill a need, overnight lighting serves a useful purpose. However, leaving more lights turned on than necessary constitutes a waste of energy. In many cases, there is no need to illuminate a part of a building in which no one is expected to be present. Interviewing more building managers may yield additional applications of overnight lighting that provide a distinction between use and waste of overnight lighting for the entire building stock.

Minimizing overnight lighting is an easy way to contribute to carbon reduction efforts.

Our study uncovered a few reasons as to why people leave lights on at night. Some reasons were useful applications of overnight lighting that filled a need, while others constituted waste. By eliminating as much of the waste as possible, building managers can conserve energy and help reduce carbon dioxide emissions from the building stock. Eliminating waste entails providing a minimum amount of lighting to fulfill a particular need. For example, multiple light switches that control the lights in sections of a large office allow employees to fully illuminate only the part of the floor on which they are working. Similarly, a night manager can turn off the lights in stairwells if he knows that there are no employees in the building who will need to access them. Such practices of using overnight lighting in an efficient manner help reduce carbon emissions by minimizing unnecessary power consumption.

Recommendations

In this chapter we outline our recommendations to CaRB for continuing research on overnight lighting in the non-domestic stock and building the findings of this preliminary study in this field. First we present our general recommendations for future studies of energy use in non-domestic buildings. Second, we present our suggestions for conducting field work and collecting overnight lighting data.

Research Recommendations for Future Studies

Conduct additional studies inbuildings

We recommend conducting additional studies inside of buildings. Researchers should gather information that is more detailed on lighting from buildings in the study. We were only able to study one building in detail, but the results we gathered were extremely useful in assessing the accuracy of our methodology. The building we studied was an open plan office; we were unable to study a cellular office layout. By testing our methodology under varying conditions, such as in cellular offices as well as open plan offices, researchers can determine which characteristics of buildings results in more and less accurate results. Additionally, researchers should compare estimates of power consumption due to lighting produced by our methodology against a known power consumption, specifically when varying parts of a building are illuminated. Such testing will further refine the methodology and allow researchers to obtain results of greater accuracy.

Establish contact with environmental conservation groups such as Global Action Plan.

We recommend contacting other energy saving programs. One problem we encountered when studying buildings in detail is contacting the building manager and arranging to view the building at night. However, there are organizations, such as the Global Action Plan, who work with many building managers to reduce waste. As these organizations work inside buildings, they have access to make detailed observations that researchers can use. In addition, since these organizations work with building managers they could provide researchers with direct contact for interviews. These interviews can lead to the possibilities of more detailed studies of individual buildings. A symbiotic relationship would further the causes of both the researchers and environmental conservation programs by yielding better results and raising awareness about energy waste.

Implement a more efficient numbering system.

We recommend implementing a more efficient numbering system for the buildings. For future studies in new geographical areas, we recommend assigning building identification by physical location. A numbering scheme based on where each building is located will more easily allow future researchers to determine where each building is and correlate that to data collected in the field.

Perform a broader study of overnight lighting.

We recommend performing a broader study of overnight lighting. The study should encompass as much of Greater London area as possible. Our project only focused on a small section of London, which provided us with a way to test our methodology as well as provided some limited results. However, to create an accurate model of overnight lighting in non-domestic buildings a larger study must be completed. When considering buildings for this larger study, the researchers must be sure to pick a representative sample of buildings. This sample must fit with both the local area as well as London as a whole. Ensuring a representative sample would create a detailed model that will allow for comprehensive statistical extrapolations to be made.

A broader study of overnight lighting in the non-domestic stock should also incorporate shops in addition to office buildings in order to produce a more robust set of data on. The inclusion of ground level shops would also provide more complete data and more accurate estimates of power consumption from overnight lighting in buildings that include office and retail space.

Operational Suggestions for Field Work

Divide tasks among team members.

We recommend dividing the tasks among the group members. After our last observation, we determined the best way to split tasks was to divide into two subgroups. By following the guidelines outlined below we were able to save a significant amount of time on our final nighttime observation.

The first group should consist of two people, one person taking pictures and one person to record information about each photograph, such as building number or façade. The person recording information should also have a map to aid in identifying buildings and guiding the group to the next building. The second group would be responsible for recording observations in the field, such as counting illuminated windows, types of bulbs noticed, or obstructions in the windows that may block light. Both members of the second group would have the same tasks to help reduce errors in counting windows. In addition, the second group should have their own copy of a map to help identify buildings without slowing down the first group.

Break up the area of study into manageable sections.

We recommend breaking the area up into manageable sections. We broke the area of study into nine separate sections to facilitate nighttime observations, and broke each section into individual blocks. The sections should approximately take the same amount of time to cover. We kept the section and blocks as a way to group buildings in a geographic manner as well as a simple way to keep the buildings organized.

Take high resolution photographs.

We recommend using a high resolution camera to photograph the buildings. One use of high resolution cameras is for confirming results gathered in the field. For instance, if the number of illuminated windows for a particular building is called into question one could easily check the photograph. This does not supplement the need to count windows while in the field, for it is much easier to count windows while making observations rather than waiting until the next day.

Another use for high resolution photographs is for detailed analysis of buildings. It is possible to actually see bulb types and determine rough estimates of power consumption. This would normally require binoculars, but with high resolution photographs it is possible to view such details. The one caveat to this method is those details cannot be determined in the field, it must wait until the next day when the pictures can be analyzed on a computer.

There are several important details with regards to using a camera. One, a tripod must be used for any nighttime pictures. To take a picture at night it requires a long exposure, without a tripod the resulting picture would be extremely blurry. However, with a tripod, it is extremely easy to take detailed and useful pictures as outlined above. A second detail to note is that a high resolution camera, such as a Single Lens Reflex camera, will allow for much more detailed images, both in final resolution and reduced image noise. While image noise can be frustrating to deal with, by using a tripod and allowing for long exposures it can be greatly reduced no matter what type of camera used.

To keep track of all the photographs taken, an organized structure must be created. We suggest using a similar structure to the one found in Figure 9 in the Methods section, as this allowed us to easily organize and view photographs. To aid in the organization we suggest creating a simple computer program, though it is possible to name and organize all of the photographs manually.

Interview more building managers.

We recommend interviewing more building managers. For our project, we were only able to schedule interviews with four building managers. While this allowed us to gather a limited insight to nighttime practices in buildings, we realize that more information must be obtained. One part of our project attempted to establish a definition of use versus waste of overnight lighting in the non-domestic stock, but due to our limited amount of interviews we were unable to adequately describe useful and wasteful practices for all buildings. By interviewing more building managers, a future study will be able to define more thoroughly what consists of use or waste of overnight lighting. With these definitions in hand, a detailed model of overnight lighting, including reasons why it cannot be entirely eliminated, can be completed.

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Appendix A: Sponsor Description

The sponsoring organization for this IQP was Carbon Reduction in Buildings (CaRB). CaRB is a part of the larger Carbon Vision Buildings (CVB) project. CVB was started in the autumn of 2004 to study ways to reduce the carbon emissions from energy use in buildings in the United Kingdom. CaRB is composed of approximately twenty researchers from five universities in the UK. This project is funded by two organizations, the Engineering and Physical Sciences Research Council (EPSRC) and the Carbon Trust. The EPSRC is the main UK agency for funding research and training in engineering and the physical sciences, and the Carbon Trust is an independent company funded by the UK government whose role is to help the UK move to a low-carbon economy.

The reduction of carbon emissions has been a world-wide goal for many years now, especially since the United Nations created the Kyoto Protocol in 1997. The Kyoto Protocol is an international agreement to cut global carbon emissions by 5% by 2008-2012. Currently, 165 nations have ratified the Kyoto Protocol, including developed and developing nations. While the United Kingdom produces only 4.3% of the global carbon emissions, it ratified the protocol and took an aggressive stance on reducing its carbon emissions (United Nations Framework Convention on Climate Change, 2006).

CVB was created to help the United Kingdom reach its goal of carbon emissions reduction. CaRB, our sponsor organization, falls under the umbrella of CVB programs. CaRB studies energy consumption in buildings as a way to reduce carbon emissions. Heating and powering electrical appliances in buildings are significant causes of carbon emissions (Carbon Reduction in Buildings, 2004). Since buildings represent about half of the nation's energy use and carbon emissions, they are a logical target for cuts in emission (CaRB, 2004). The main goal of CaRB is the development of a socio-technical model to predict carbon emissions from buildings at the local, community, city, and national levels. Additionally, the model will predict the effectiveness of efforts to reduce carbon emissions. Data that results from this work will be distributed to researchers and policy-makers to provide guidance and tools in helping the transition to a low-carbon economy. The United Kingdom hopes that work by research organizations including CaRB will result in a 50% reduction in carbon emissions from buildings by the year 2030 (Carbon Trust, 2006).

Appendix B: Minutes from Interview with Global Action Plan

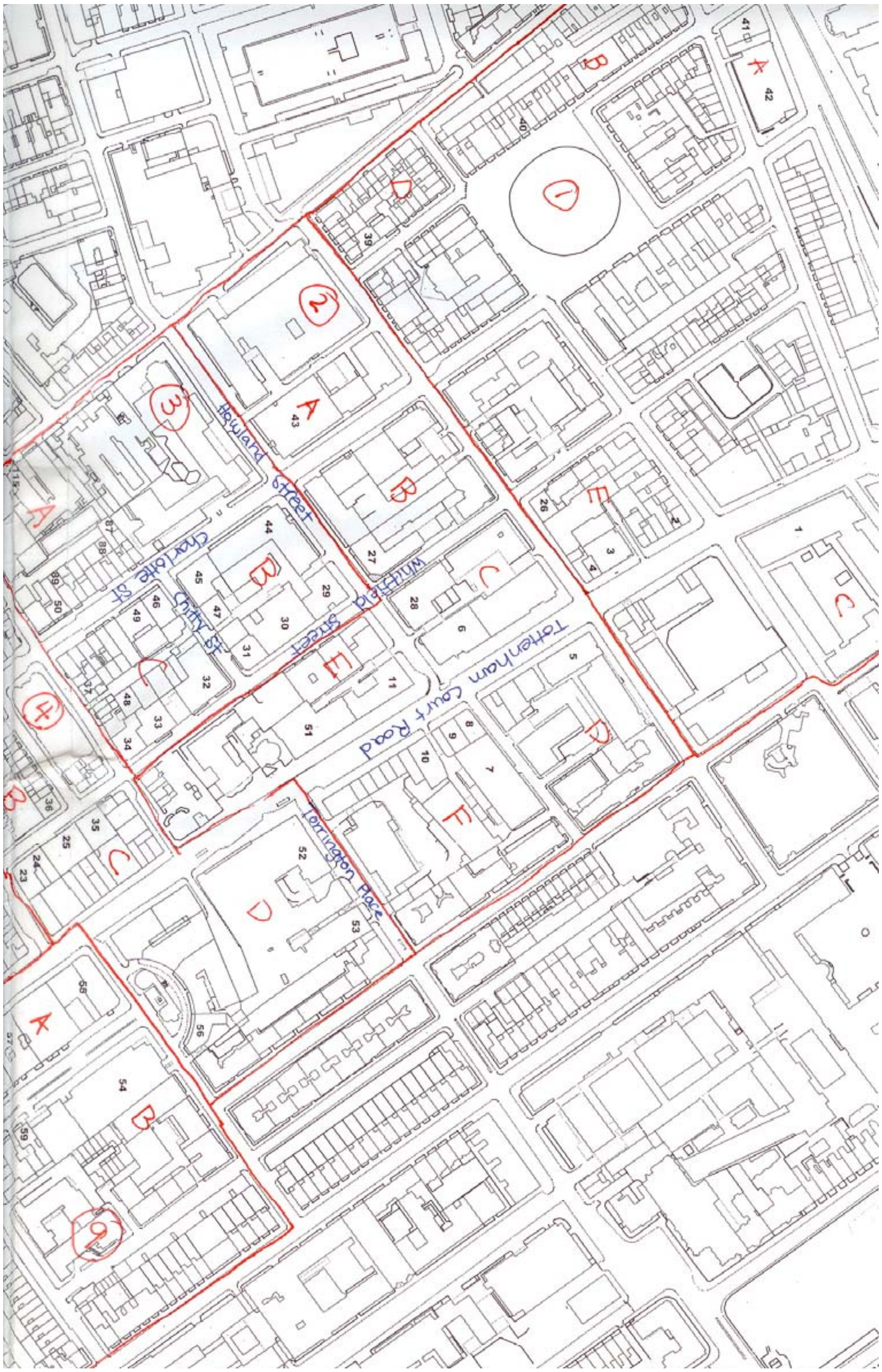
Interview Subject: Chris Large
Team Members Present: Jonathan Levin, Thomas Niemczycki, Vanessa Walton, Ian Woloschin
Date: January 29, 2007 at 2:00 p.m.

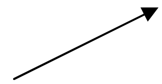
Proceedings:

- Introductions
- Chris began to cover what their methodology was and how they conducted their overnight lighting study
- GAP used a one mile city route
- Counted windows lit and not lit
- Questioned space in each building, and how many lights were on
- Spoke to the City of London, in which they were told the TOTAL amount of space of all buildings in the area
- With this area they figured out the average amount of lighting in the office space
- Our group's problem: how to correlate what we see to the amount of electricity used
- GAP used the Lighting Industry Federation's max value of 35 watts/sq meter, and also used the value of 12.5 watts/sq meter, which is the "good" amount an office should use
- GAP observed 7000 windows and found 44% windows to be lit, which they then correlated this to 44% offices to be lit, they then took the total office space to estimate the amount of lighting per office space
- They estimated how many hours people were using the buildings, and assumed 8am-7pm to be usage, and any lights on after that time would be considered wastage
- They went out 11pm-12am to conduct their study (3 or 4 of the buildings they found to have cleaners or designers working inside so they considered that to be usage) with 4 people in just one hour
- Chris recommended we look at the "Times" where they took a picture of Canary Wharf at midnight on a Sunday in the Docklands, and the whole area was lit up
- We asked how would you go about figuring out if windows were illuminated or not?
  If they could see ANY lights they counted the window as being lit. They rounded down, and took out some buildings that they weren't sure about. They also said they took the low cost of energy rather than the high.
- How did you deal with open plan?
  Counted them as all being lit.
- Once they got the area, they looked at the CO_2 emissions and then they used the standard (.43). We can look up what the standards are
- How did you deal with external lighting?
  They looked at the inside of buildings only, and noted if computers were left on.
- They did not consider ground level shops at all
- They worked with 50 buildings in "environment champions" and figured 11% reduction in energy use
- Chris provided us with a website that would be helpful:
  http://www.mondiale.co.uk/monodarc/LIF24.html

Appendix C: Map of Area of Study

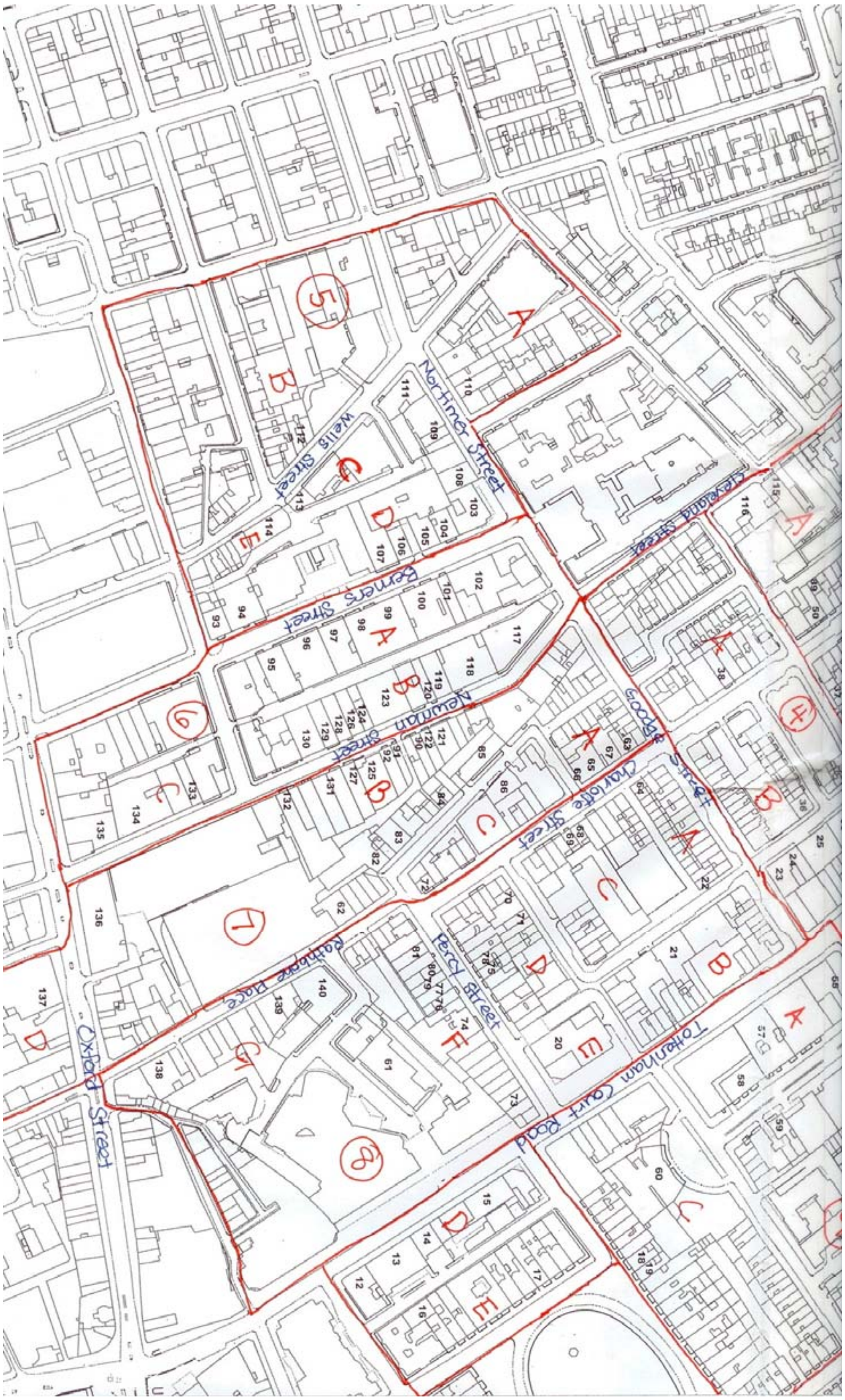
Northern Half of Area of Study





- Sections are identified by circled number
- Blocks are identified by letter
- Sample buildings are identified by Survey ID numbers

Southern Half of Area of Study



North

- Sections are identified by circled number
- Blocks are identified by letter
- Sample buildings are identified by Survey ID numbers

Appendix D: Field Data Collection Sheet

Recorder: ________________

Date:

Time	Survey ID	Section	Block ID	Nr Façades of Bdg	Layout	Bulb Type	Interview?	People	Comments
					Cellular Open Plane Other				
					Cellular Open Plane Other				
					Cellular Open Plane Other				
					Cellular Open Plane Other				
					Cellular Open Plane Other				
					Cellular Open Plane Other				
					Cellular Open Plane Other				
					Cellular Open Plane Other				

Appendix E: Building Manager Interview Questions

We are a group of four students working with a UCL research group called Carbon Reduction in Buildings (CaRB, www.carb.org.uk). We are studying overnight lighting in non-domestic buildings. Please note that your name will not be attached to any of these responses. Feel free to omit any questions that you do not wish to answer. Please provide answers to the best amount of detail that you wish about overnight lighting for your building.

1. What is your role in this building?
2. Can you provide us with any of the following building specifications:
    a. What are the primary uses of this building?
    b. How much of the building is used for non-domestic activities?
    c. How are the floors laid out (open plan or cellular)?
    d. How many rooms per floor?
    e. What is the average size of the rooms?
3. Do you ever see the building at night?
4. During which hours of the day is the building occupied?
5. How late do people typically work in this building?
6. Are there cleaners who come in at night? If yes, do you know what time of the night and for how long?
7. Are there lights left on in this building at night? Please indicate why or why not.
8. Which rooms or areas are lit overnight?
9. Where are the light switches located for office spaces?
10. What kinds of switches are there? (e.g. motion sensors)
11. Does one switch turn on all the lights in a room?
12. Are people asked to turn the lights off if they are the last to leave the office?
13. Are there any other activities that go on at night that require lighting?
14. What types of light bulbs are used?
15. About how many light bulbs are used in each room?
16. Do you have an estimate of how much energy is consumed by lighting in this building?

Appendix F: Photo Tracking Sheet

Pic #	Section ID	Block ID	Map (survey) ID	Orientation	Façade	Notes

Appendix G: Computer Program for Organizing Observation Photos

```
# building_sorter.py
# ******** Description ********
# A quick and simple Python program to help the Carbon IQP sort all of the
pictures of buildings
# from the daytime and nighttime observations.
# **************************
# Ian Woloschin
# Carbon IQP
# C Term 2007
# Worcester Polytechnic Institute
# 7.02.2007

# Import the os and sys Python modules
import os
import sys

# Prefix and suffix of the image files from the camera
img_prefix = "IMG_"
img_suffix = ".JPG"

# Counter to keep track of if the user skips any images
skipped_img = 0

# Picture number offset, can be used if the program crashes and the users
wishes to start after Picture 1
pic_offset = 0

# Clears the console screen
os.system("cls")

# Print script title
print "\
Building Sorter\n\
Created by Ian Woloschin\n\
Carbon IQP\n\
WPI\n\
C Term 2007\n\n"

# Collect general information about picture group
date = raw_input("Date pictures were taken (DD.MM.YY): ")
first_picture = input("Number of the first picture: ")
total_pictures = input("Number of pictures: ")
orig_directory = raw_input("Source Directory:\n")
sorted_directory = raw_input("Destination Directory:\n")

# Check picture source directory, exit if wrong
print "\n\nIs this the correct source directory:\n",orig_directory
test_orig = raw_input("(y/n)")
if test_orig != "y":
	sys.exit()

# Check the picture destination directory, exit if wrong
print "\n\nIs this the correct destination directory:\n",sorted_directory
test_dest = raw_input("(y/n)")
if test_dest != "y":
	sys.exit()

# Checks for outer directory, creates if it doesn't exist
```

```
if ~os.path.exists(sorted_directory):
      md_sorted = "mkdir \"" + sorted_directory + "\""
      os.system(md_sorted)

# Creates a "Table of Contents" file
toc_filename = "TOC - " + date + ".txt"
toc_fullpath = sorted_directory + "\\" + toc_filename
print toc_fullpath
toc = open(toc_fullpath, 'w')

# Loops through "total_pictures" times
for index in range(total_pictures):
      # Clears the console screen
      os.system("cls")

      # Determines picture number (IMG_XXXX.JPG) to be copied
      cam_img_num = repr(first_picture + index).zfill(4)

      # Creates the original filename of the picture and original full path
      old_filename = img_prefix + cam_img_num + img_suffix
      old_fullpath = "\"" + orig_directory + "\\" + old_filename + "\""

      print "\nPicture ",index + 1 - skipped_img + pic_offset,"\tCamera
Number",cam_img_num,"\n"

      # View Picture
      print "View Picture (y/n)?"
      view = raw_input()

      if view == "y":
            os.startfile("\"" + old_fullpath + "\"")
      elif view == "Y":
            os.startfile("\"" + old_fullpath + "\"")

      # Skip Picture
      print "Skip Picture (y/n/s)?"
      skip = raw_input()

      # If a "s" is entered the Picture Number will be updated, but no picture
will be copied
      if skip == 'y':
            skipped_img+=1
            continue
      elif skip == 'Y':
            skipped_img+=1
            continue
      elif skip == "s":
            continue
      elif skip == "S":
            continue

      # Section ID
      print "Section ID?"
      section = raw_input()

      # Block ID
      print "Block ID?"
      block = raw_input()

      # Building ID
      print "Building ID?"
      building = input()

      # Ensures the Building ID has leading zeroes if not a three digit number
```

```
        building = str(building).zfill(3)

        # Façade Orientation (Cardnial Directions)
        print "Orientation of Façade (Direction and number if any)?"
        orientation = raw_input()

        # Creates new filename of the picture
        new_filename = building + "_" + orientation + "_" + date + img_suffix

        # Creates new directory names and makes the directories if they do not
exist
        new_directory = sorted_directory + "\\" + date
        if os.path.exists(new_directory) == False:
              md_cmd = "mkdir \"" + new_directory + "\""
              os.system(md_cmd)

        new_directory = new_directory + "\\Section " + section
        if os.path.exists(new_directory) == False:
              md_cmd = "mkdir \"" + new_directory + "\""
              os.system(md_cmd)

        new_directory = new_directory + "\\Block " + block
        if os.path.exists(new_directory) == False:
              md_cmd = "mkdir \"" + new_directory + "\""
              os.system(md_cmd)

        new_directory = new_directory + "\\" + building
        if os.path.exists(new_directory) == False:
              md_cmd = "mkdir \"" + new_directory + "\""
              os.system(md_cmd)


        # Creates the fullpath to the new location of the picture
        new_fullpath = "\"" + new_directory + "\\" + new_filename + "\""

        # Copies the original picture to the new directory and renames the new
picture
        cp_cmd = "copy " + old_fullpath + " " + new_fullpath
        os.system(cp_cmd)

        toc_output = str(cam_img_num) + "\t" \
              + str(index + 1 - skipped_img + pic_offset) + "\t" \
              + section + "\t" + block + "\t" + str(building) + "\t" \
              + orientation + "\n"

        toc.write(toc_output)

# Closes "Table of Contents" file
toc.close()

# End of Script
```

Appendix H: Pilot Study Observation Data

Survey ID	Street	Street Number	Visible Façades	Total Number of Windows
23	Whitfield St	30	2	51
24	Whitfield St	32	1	12
25	Whitfield St	40	1	40
35	Whitfield St	44-46	1	15
36	Scala St	24	2	32

Table 1: Daytime Observation Building Data

Survey ID	Time	Illuminated Windows	Observed People
23	20:00	33	No
24	19:57	9.5*	No
25	19:55	18	No
35	19:55	6	No
36	19:58	2	No

Table 2: Observation Data from January 16

Survey ID	Time	Illuminated Windows	Observed People
23	20:34	34	None Visible**
24	20:32	10	No
25	20:30	22	No
35	20:27	7	No
36	20:39	6	No

Table 3: Observation Data from January 17

Survey ID	Night 1 % illuminated	Night 2 % illuminated
23	64.71%	66.67%
24	79.17%	83.33%
25	45.00%	55.00%
35	40.00%	46.67%
36	6.25%	18.75%
Average:	47.02%	54.08%

Table 4: Pilot Study Analysis

*Window extended into two rooms, one of which was illuminated and the other not illuminated.
**Lights turned off during our observation, but no people were visible.

Appendix I: Building Identification

ID	Survey ID	Section	Block	Street	Street Address	House Name
105	1	1	C	Alfred Pl	149	Whittington House
106	2	1	E	Alfred Pl	118	Null
107	3	1	E	Alfred Pl	110-113	Null
108	4	1	E	Alfred Pl	109-a	Null
109	5	2	D	Alfred Pl	170	Null
110	6	2	C	Bedford Ave	97	Null
25	7	2	F	Bedford Sq	2-10-11-20	Null
111	8	2	F	Bedford Sq	175-176	Null
112	9	2	F	Bedford Sq	177-178	Null
113	10	2	F	Berners St	180	Wolverstone House
114	11	2	E	Berners St	90	Null
6	12	9	D	Berners St		Null
115	13	9	D	Berners St	251	Orwell House
116	14	9	D	Berners St	248	Marchpole House
117	15	9	D	Berners St	247	Null
48	16	9	E	Berners St	16	Null
7	17	9	E	Berners St	32	British Music House
8	18	9	C	Berners St	26	Null
9	19	9	C	Berners St	25	Null
81	20	8	E	Berners St	22	Newlands House
126	21	8	B	Berners St	12_14	Null
127	22	8	A	Berners St	27-29	Null
129	23	4	C	Berners St	30	Michelle House
128	24	4	C	Berners St	32	Berners House
130	25	4	C	Capper St	40	Shropshire House
51	26	1	E	Charlotte Mws	10	Null
49	27	2	B	Charlotte St	18	Null
131	28	2	C	Charlotte St	76-80	Null
132	29	3	B	Charlotte St	89	Null
133	30	3	B	Charlotte St	81	Ariel House
134	31	3	B	Charlotte St	67-69	Null
135	32	3	C	Charlotte St	65	Null

136	33	3	C	Charlotte St	45-51	Null
137	34	3	C	Charlotte St	43	Null
138	35	4	C	Charlotte St	44-46	Null
100	36	4	B	Charlotte St	24	Null
122	37	3	C	Charlotte St	30	Null
27	38	4	A	Charlotte St	59	Null
44	39	1	D	Charlotte St	1	Null
46	40	1	B	Cheenie St	26	Fitzroy House
45	41	1	A	Chitty St	26-28	Null
52	42	1	A	Cleveland St	355	Middlesex House
47	43	2	A	Cleveland St	13	Null
50	44	3	B	Conway St	23	Null
28	45	3	B	Conway St	80	Null
29	46	3	C	Fitzroy Sq	76-78	Richmond Towers
41	47	3	B	Fitzroy St	10_15	Null
26	48	3	C	Horwell St	7_10	Null
30	49	3	C	Howland St	74	Null
31	50	3	A	Howland St	77-79	Null
118	51	2	E	Maple St	85	Null
103	52	4	D	Marylebone Rd	2_16	Fitzroy House
104	53	4	D	Mortimer St	22	Null
1	54	9	B	Mortimer St	19-30	Null
2	55	9	A	Mortimer St	15	Null
40	56	4	D	Mortimer St	11	Mortimer House
3	57	9	A	Newman St	10	Null
4	58	9	A	Newman St	1	Null
5	59	9	B	Newman St	34	Null
102	60	9	C	Newman St	25	Null
101	61	8	F	Newman St	21	Null
91	62	7	B	Newman St	34	Null
32	63	7	A	Newman St	43-45	Kensick House
33	64	8	A	Newman St	38	Null
34	65	7	A	Newman St	33a	Null
35	66	7	A	Newman St	33b	Null
36	67	7	A	Newman St	39	Null
37	68	8	C	Newman St	26	Null
38	69	8	C	Newman St	24	Rila House

139	70	8	D	Newman St	2	Null
140	71	8	D	Newman St	5	Null
39	72	7	C	Newman St	1	Null
82	73	8	F	Newman St	18	Null
83	74	8	F	Newman St	10_11	Null
84	75	8	D	Newman St	32	Null
85	76	8	F	Newman St	8	Null
86	77	8	F	Newman St	7	Null
87	78	8	D	Newman St	33	Null
88	79	8	F	Newman St	6	Null
89	80	8	F	Newman St	5	Null
90	81	8	F	Oxford St	3	Oxford House
97	82	7	B	Oxford St	7	Gainsborough House
98	83	7	B	Percy St	15	Met Building
96	84	7	B	Percy St	25	Null
95	85	7	B	Percy St	29-35	Null
99	86	7	C	Percy St	24	Null
119	87	3	A	Percy St	13	Null
120	88	3	A	Percy St	11_112	Null
121	89	3	A	Percy St	7	Null
57	90	7	B	Percy St	28	Null
58	91	7	B	Percy St	26	Null
59	92	7	B	Percy St	25	Null
10	93	5	D	Rathbone Pl	61	Couney House
11	94	5	D	Rathbone Place	58-60	Null
12	95	6	A	Rathbone Place	14-15	Null
13	96	6	A	Rathbone Place	16-18	Null
14	97	6	A	Rathbone St	19-20	Null
15	98	6	A	Rathbone St	21	Null
16	99	6	A	Rathbone St	22	Null
17	100	6	A	Rathbone St	25-27	Null
18	101	6	A	Rathbone St	28	Null
19	102	6	A	Scala St	29-33	Null
20	103	5	D	Stephen St	40	Null
21	104	5	D	Store St	42	Null
22	105	5	D	Torrington Pl	43-44	Brooke House

23	106	5	D	Torrington Pl	45-46	Null
24	107	5	D	Tottenham Court Rd	47	Maple House
53	108	5	D	Tottenham Court Rd	19-21	Null
54	109	5	D	Tottenham Court Rd	27	Project House
55	110	5	A	Tottenham Court Rd	16	Null
56	111	5	D	Tottenham Court Rd	37-41	Null
123	112	5	B	Tottenham Court Rd	66-67	The Network Building
124	113	5	C	Tottenham Court Rd	24	Null
125	114	5	E	Tottenham Court Rd	19-23	Buttler House
42	115	3	A	Tottenham Court Rd	34-42	Queens House
43	116	3	A	Tottenham Court Rd	30	Null
60	117	6	B	Tottenham Court Rd	55	Null
61	118	6	B	Tottenham Court Rd	60-62	Null
62	119	6	B	Tottenham Court Rd	64	Null
63	120	6	B	Tottenham Court Rd	65	Null
64	121	7	B	Tottenham Mws	30	Null
65	122	7	B	Tottenham Mws	29	Null
66	123	6	B	Tottenham Mws	68	Null
67	124	6	B	Tottenham St	72	Null
68	125	7	B	Wells St	23-24	Welbeck House
69	126	6	B	Wells St	73	Linton House
70	127	7	B	Wells St	22	Null
71	128	6	B	Whitfield St	74	Kirkman House
72	129	6	B	Whitfield St	75	Cyclone House
73	130	6	B	Whitfield St	77	Null
74	131	7	B	Whitfield St	20	Whitfield court
75	132	7	B	Whitfield St	17-17a	Null
76	133	6	C	Whitfield St	84	Null
77	134	6	C	Whitfield St	87-91	Whitfield House
78	135	6	C	Whitfield St	93	Null
79	136	7	B	Whitfield St	76	Null
80	137	7	D	Whitfield St	81	Asta House
92	138	8	G	Whitfield St	3_5	Null
93	139	8	G	Whitfield St	16	Null
94	140	8	G	Whitfield St	19-22	Null

Appendix J: Physical Characteristics of Buildings

Survey ID	Section	Block	Number of Floors	Area per Floor (m^2)	Total Area (m^2)	Floor Space Category	Central Air Conditioning
1	1	C	8	2164	17312	10,000-30,000	Not identified
2	1	E	4	38.66	154.64	101-300	Not identified
3	1	E	5	414.1	2070.5	1,000-3,000	Diffusers
4	1	E	4	75.51	302.04	300-1,000	Not identified
5	2	D	6	813.82	4882.92	3,000-10,000	Diffusers
6	2	C	6	743.5	4461	3,000-10,000	Not identified
7	2	F	6	1285	7710	3,000-10,000	Cassettes
8	2	F	6	198	1188	1,000-3,000	Cassettes
9	2	F	7	193.9	1357.3	1,000-3,000	Diffusers
10	2	F	5	359.6	1798	1,000-3,000	Not identified
11	2	E	6	609.6	3657.6	3,000-10,000	Not identified
12	9	D	6	416.6	2499.6	1,000-3,000	Diffusers
13	9	D	7	671.4	4699.8	3,000-10,000	Cassettes
14	9	D	6	221.9	1331.4	1,000-3,000	Cassettes
15	9	D	6	984.78	5908.68	3,000-10,000	Diffusers
16	9	E	4	189.1	756.4	300-1,000	Diffusers
17	9	E	3	165	495	300-1,000	Not identified
18	9	C	4	150.1	600.4	300-1,000	Not identified
19	9	C	4	147.7	590.8	300-1,000	Not identified
20	8	E	9	899.8	8098.2	3,000-10,000	Cassettes
21	8	B	4	474.1	1896.4	1,000-3,000	None
22	8	A	3	73.27	219.81	101-300	None
23	4	C	4	252.9	1011.6	1,000-3,000	None
24	4	C	4	190.95	763.8	300-1,000	Not identified
25	4	C	5	499.1	2495.5	1,000-3,000	Diffusers
26	1	E	5	171.6	858	300-1,000	None
27	2	B	5	547.9	2739.5	1,000-3,000	None
28	2	C	5	719	3595	3,000-10,000	Diffusers
29	3	B	6	456.8	2740.8	1,000-3,000	Cassettes
30	3	B	5	882.5	4412.5	3,000-10,000	Diffusers
31	3	B	5	268.4	1342	1,000-3,000	None
32	3	C	4	729.4	2917.6	1,000-3,000	None
33	3	C	4	392.1	1568.4	1,000-3,000	Cassettes

34	3	C	5	321.6	1608	1,000-3,000	Cassettes
35	4	C	5	339.4	1697	1,000-3,000	None
36	4	B	5	137.3	686.5	300-1,000	Diffusers
37	3	C	4	78.23	312.92	300-1,000	Not identified
38	4	A	5	163.8	819	300-1,000	None
39	1	D	5	130.8	654	300-1,000	None
40	1	B	4	96.09	384.36	300-1,000	Not identified
41	1	A	5	365.2	1826	1,000-3,000	Diffusers
42	1	A	4	1099	4396	3,000-10,000	Not identified
43	2	A	6	1293	7758	3,000-10,000	Diffusers
44	3	B	6	1183	7098	3,000-10,000	Cassettes
45	3	B	6	455.6	2733.6	1,000-3,000	Not identified
46	3	C	6	274.5	1647	1,000-3,000	Diffusers
47	3	B	4	435.6	1742.4	1,000-3,000	None
48	3	C	3	177.5	532.5	300-1,000	Not identified
49	3	C	6	296.8	1780.8	1,000-3,000	Diffusers
50	3	A	5	195.6	978	300-1,000	Cassettes
51	2	E	6	921.9	5531.4	3,000-10,000	Diffusers
52	4	D	6	940.89	5645.34	3,000-10,000	Not identified
53	4	D	7	696.8	4877.6	3,000-10,000	None
54	9	B	7	1751	12257	10,000-30,000	Diffusers
55	9	A	4	870.8	3483.2	3,000-10,000	Not identified
56	4	D	5	281.3	1406.5	1,000-3,000	Not identified
57	9	A	5	840.56	4202.8	3,000-10,000	Diffusers
58	9	A	5	525.15	2625.75	1,000-3,000	Cassettes
59	9	B	5	203.7	1018.5	1,000-3,000	Cassettes
60	9	C	7	1150	8050	3,000-10,000	None
61	8	F	6	792.8	4756.8	3,000-10,000	None
62	7	B	5	274.5	1372.5	1,000-3,000	None
63	7	A	5	156.94	784.7	300-1,000	None
64	8	A	4	50.09	200.36	101-300	Not identified
65	7	A	5	312.1	1560.5	1,000-3,000	Not identified
66	7	A	5	26.77	133.85	101-300	Cassettes
67	7	A	5	393.3	1966.5	1,000-3,000	Not identified
68	8	C	5	69.06	345.3	300-1,000	Not identified
69	8	C	5	63.42	317.1	300-1,000	Not identified
70	8	D	5	61.96	309.8	300-1,000	Cassettes
71	8	D	5	204.3	1021.5	1,000-3,000	Diffusers
72	7	C	5	80.07	400.35	300-1,000	None

73	8	F	4	121.4	485.6	300-1,000	Not identified
74	8	F	4	717.3	2869.2	1,000-3,000	Diffusers
75	8	D	4	74.84	299.36	101-300	None
76	8	F	4	87.95	351.8	300-1,000	Not identified
77	8	F	4	162	648	300-1,000	Not identified
78	8	D	5	133.7	668.5	300-1,000	None
79	8	F	4	127.4	509.6	300-1,000	Not identified
80	8	F	4	81.39	325.56	300-1,000	None
81	8	F	4	160.7	642.8	300-1,000	Not identified
82	7	B	4	613.8	2455.2	1,000-3,000	Cassettes
83	7	B	5	231.3	1156.5	1,000-3,000	Not identified
84	7	B	4	51.31	205.24	101-300	Diffusers
85	7	B	4	304.1	1216.4	1,000-3,000	Not identified
86	7	C	7	243.8	1706.6	1,000-3,000	Diffusers
87	3	A	3	121.7	365.1	300-1,000	Diffusers
88	3	A	4	162.07	648.28	300-1,000	Diffusers
89	3	A	3	58.42	175.26	101-300	Not identified
90	7	B	4	151.5	606	300-1,000	Not identified
91	7	B	4	118.6	474.4	300-1,000	Not identified
92	7	B	5	221.6	1108	1,000-3,000	None
93	5	D	5	447.86	2239.3	1,000-3,000	Diffusers
94	5	D	6	573.3	3439.8	3,000-10,000	Not identified
95	6	A	7	478.2	3347.4	3,000-10,000	Diffusers
96	6	A	6	705.2	4231.2	3,000-10,000	Both D&C
97	6	A	6	477.8	2866.8	1,000-3,000	None
98	6	A	6	331.54	1989.24	1,000-3,000	None
99	6	A	6	768.67	4612.02	3,000-10,000	None
100	6	A	6	714.8	4288.8	3,000-10,000	Not identified
101	6	A	6	209.5	1257	1,000-3,000	None
102	6	A	6	749.6	4497.6	3,000-10,000	Cassettes
103	5	D	7	469.1	3283.7	3,000-10,000	Cassettes
104	5	D	6	212.1	1272.6	1,000-3,000	Not identified
105	5	D	6	257.1	1542.6	1,000-3,000	None
106	5	D	5	284.8	1424	1,000-3,000	Not identified
107	5	D	6	490.7	2944.2	1,000-3,000	Not identified
108	5	D	4	274.3	1097.2	1,000-3,000	Both D&C
109	5	D	5	564.77	2823.85	1,000-3,000	Diffusers
110	5	A	5	236.5	1182.5	1,000-3,000	Not identified
111	5	D	5	397.3	1986.5	1,000-3,000	Cassettes

112	5	B	4	212.95	851.8	300-1,000	None
113	5	C	5	115.1	575.5	300-1,000	Not identified
114	5	E	6	345	2070	1,000-3,000	Not identified
115	3	A	5	1141.52	5707.6	3,000-10,000	None
116	3	A	5	648.9	3244.5	3,000-10,000	Diffusers
117	6	B	5	789.9	3949.5	3,000-10,000	Diffusers
118	6	B	5	731.2	3656	3,000-10,000	None
119	6	B	5	294.7	1473.5	1,000-3,000	Cassettes
120	6	B	5	149.4	747	300-1,000	Not identified
121	7	B	5	263.6	1318	1,000-3,000	Diffusers
122	7	B	4	149.6	598.4	300-1,000	None
123	6	B	5	685.4	3427	3,000-10,000	Diffusers
124	6	B	5	84.92	424.6	300-1,000	None
125	7	B	6	471.5	2829	1,000-3,000	Cassettes
126	6	B	4	223.2	892.8	300-1,000	Not identified
127	7	B	5	292.2	1461	1,000-3,000	None
128	6	B	6	247	1482	1,000-3,000	Not identified
129	6	B	4	254.2	1016.8	1,000-3,000	Not identified
130	6	B	6	434	2604	1,000-3,000	Not identified
131	7	B	5	669.6	3348	3,000-10,000	Diffusers
132	7	B	5	707.1	3535.5	3,000-10,000	Not identified
133	6	C	4	193.2	772.8	300-1,000	Not identified
134	6	C	5	968	4840	3,000-10,000	Not identified
135	6	C	5	541	2705	1,000-3,000	Not identified
136	7	B	8	1227	9816	3,000-10,000	Cassettes
137	7	D	7	1638.8	11471.6	10,000-30,000	Not identified
138	8	G	4	472.7	1890.8	1,000-3,000	Not identified
139	8	G	5	603.3	3016.5	3,000-10,000	Cassettes
140	8	G	6	648.3	3889.8	3,000-10,000	Cassettes

Note: Data on Area per Floor and Central Air Conditioning are from previous CaRB studies.

Appendix K: Building Data from Daytime Observations

Survey ID	Section	Block	Included Floors	Counted Floors	Included Floor Space (m^2)
1	1	C	1-7	7	15148.00
2	1	E	0-3	4	154.64
3	1	E	1-4	4	1656.40
4	1	E	1-3	3	226.53
5	2	D	1-5	5	4069.10
6	2	C	1-5	5	3717.50
7	2	F	0-6	7	8995.00
8	2	F	1-5	5	990.00
9	2	F	1-6	6	1163.40
10	2	F	1-4	4	1438.40
11	2	E	1-5	5	3048.00
12	9	D	1-5	5	2083.00
13	9	D	1-6	6	4028.40
14	9	D	2-5	3	665.70
15	9	D	1-5	5	4923.90
16	9	E	0-3	4	756.40
17	9	E	0-2	3	495.00
18	9	C	0-3	4	600.40
19	9	C	0-3	4	590.80
20	8	E	1-9	9	8098.20
21	8	B	0-3	4	1896.40
22	8	A	0-2	3	219.81
23	4	C	1-3	4	1011.60
24	4	C	0-3	4	763.80
25	4	C	0-4	5	2495.50
26	1	E	0-5	6	1029.60
27	2	B	0-4	5	2739.50
28	2	C	0-4	5	3595.00
29	3	B	0-5	6	2740.80
30	3	B	0-4	5	4412.50
31	3	B	0-4	5	1342.00
32	3	C	0-3	4	2917.60
33	3	C	0-3	4	1568.40
34	3	C	0-4	5	1608.00
35	4	C	0-4	5	1697.00
36	4	B	1-4	5	686.50
37	3	C	0-3	4	312.92

38	4	A	1-4	5	819.00
39	1	D	0-4	5	654.00
40	1	B	0-3	4	384.36
41	1	A	0-3	4	1460.80
42	1	A	0-3	4	4396.00
43	2	A	0-5	6	7758.00
44	3	B	0-5	6	7098.00
45	3	B	0-5	6	2733.60
46	3	C	0-5	6	1647.00
47	3	B	0-3	4	1742.40
48	3	C	1-2	2	355.00
49	3	C	0-5	6	1780.80
50	3	A	1-4	4	782.40
51	2	E	1-5	5	4609.50
52	4	D	1-5	5	4704.45
53	4	D	1-6	6	4180.80
54	9	B	1-6	6	10506.00
55	9	A	1-3	3	2612.40
56	4	D	0-4	5	1406.50
57	9	A	1-4	4	3362.24
58	9	A	1-4	4	2100.60
59	9	B	0-4	5	1018.50
60	9	C	0-5	6	6900.00
61	8	F	0-5	6	4756.80
62	7	B	1-4	4	1098.00
63	7	A	1-4	4	627.76
64	8	A	1-3	3	150.27
65	7	A	1-4	4	1248.40
66	7	A	1-4	4	107.08
67	7	A	1-4	4	1573.20
68	8	C	0-4	5	345.30
69	8	C	0-4	5	317.10
70	8	D	1-4	4	247.84
71	8	D	1-4	4	817.20
72	7	C	1-4	4	320.28
73	8	F	1-3	3	364.20
74	8	F	0-3	4	2869.20
75	8	D	1-3	3	224.52
76	8	F	0-3	4	351.80
77	8	F	1-3	3	486.00
78	8	D	1-4	4	534.80
79	8	F	1-3	3	382.20
80	8	F	0-3	4	325.56

81	8	F	1-3	3	482.10
82	7	B	0-3	4	2455.20
83	7	B	1-4	4	925.20
84	7	B	1-3	3	153.93
85	7	B	0-3	4	1216.40
86	7	C	0-1	2	487.60
87	3	A	0-2	3	365.10
88	3	A	0-3	4	648.28
89	3	A	0-2	3	175.26
90	7	B	1-3	3	454.50
91	7	B	1-3	3	355.80
92	7	B	1-4	4	886.40
93	5	D	1-4	4	1791.44
94	5	D	1-5	5	2866.50
95	6	A	0-6	7	3347.40
96	6	A	0-5	6	4231.20
97	6	A	1-5	5	2389.00
98	6	A	1-5	5	1657.70
99	6	A	1-5	5	3843.35
100	6	A	1-5	5	3574.00
101	6	A	0-5	6	1257.00
102	6	A	0-5	6	4497.60
103	5	D	1-6	6	2814.60
104	5	D	0-5	6	1272.60
105	5	D	0-5	6	1542.60
106	5	D	1-4	4	1139.20
107	5	D	0-5	6	2944.20
108	5	D	0-3	4	1097.20
109	5	D	1-4	4	2259.08
110	5	A	0-4	5	1182.50
111	5	D	0-4	5	1986.50
112	5	B	1-3	3	638.85
113	5	C	0-4	5	575.50
114	5	E	0-5	6	2070.00
115	3	A	0-4	5	5707.60
116	3	A	0-4	5	3244.50
117	6	B	0-4	5	3949.50
118	6	B	0-4	5	3656.00
119	6	B	0-4	5	1473.50
120	6	B	0-4	5	747.00
121	7	B	0-4	5	1318.00
122	7	B	1-3	3	448.80
123	6	B	0-4	5	3427.00

124	6	B	1-4	4	339.68
125	7	B	1-5	5	2357.50
126	6	B	0-3	4	892.80
127	7	B	1-4	4	1168.80
128	6	B	0-5	6	1482.00
129	6	B	0-3	5	1271.00
130	6	B	0-4	6	2604.00
131	7	B	1-4	4	2678.40
132	7	B	1-4	4	2828.40
133	6	C	0-3	5	966.00
134	6	C	0-4	5	4840.00
135	6	C	1-4	4	2164.00
136	7	B	1-7	7	8589.00
137	7	D	0-6	7	11471.60
138	8	G	1-3	3	1418.10
139	8	G	1-4	4	2413.20
140	8	G	0-4	5	3241.50

Appendix L: Window Data from Daytime Observation

Survey ID	Section	Block	Visible Façades	Total Windows	Windows per Façade							
					N	NE	E	SE	S	SW	W	NW
1	1	C	3	332	7				7		318	
2	1	E	1	7		7						
3	1	E	2	42		25						17
4	1	E	1	3		3						
5	2	D	2	62						54		8
6	2	C	2	70		54		16				
7	2	F	3	250		30		143				77
8	2	F	2	57						25		32
9	2	F	1	35						35		
10	2	F	1	18						18		
11	2	E	2	151		80						71
12	9	D	3	109		29		51		29		
13	9	D	2	180		102				78		
14	9	D	1	28						28		
15	9	D	1	50						50		
16	9	E	1	39						39		
17	9	E	2	18		9				9		
18	9	C	1	11				11				
19	9	C	1	11				11				
20	8	E	3	399		293		88		18		
21	8	B	1	28						28		
22	8	A	2	21		15		6				
23	4	C	2	51					36	15		
24	4	C	1	12						12		
25	4	C	1	40						40		
26	1	E	3	50				25	5	20		
27	2	B	2	139		103		36				
28	2	C	2	105				54		51		
29	3	B	2	146		65						81
30	3	B	1	45		45						
31	3	B	3	51		19	5	27				
32	3	C	2	45		23						22
33	3	C	1	51		51						
34	3	C	2	39		7		32				
35	4	C	1	15						15		
36	4	B	3	33	4	15						14
37	3	C	1	8				8				

38	4	A	1	6		6					
39	1	D	1	39		39					
40	1	B	1	28		28					
41	1	A	4	49	15			11		20	3
42	1	A	3	120	69	12		39			
43	2	A	2	310		227	83				
44	3	B	2	277					157		120
45	3	B	2	146			80		66		
46	3	C	2	33					21		12
47	3	B	1	25			25				
48	3	C	1	8					8		
49	3	C	1	31					31		
50	3	A	1	25		25					
51	2	E	2	45		35	10				
52	4	D	1	165							165
53	4	D	1	42							42
54	9	B	2	313					240		73
55	9	A	5	103	3	36			27	4	33
56	4	D	2	36			11	25			
57	9	A	2	75		38			37		
58	9	A	1	45		45					
59	9	B	1	27					27		
60	9	C	1	91							91
61	8	F	1	100			100				
62	7	B	1	20		20					
63	7	A	1	13		13					
64	8	A	1	12					12		
65	7	A	1	21		21					
66	7	A	1	17			17				
67	7	A	1	10		10					
68	8	C	1	15					15		
69	8	C	1	13					13		
70	8	D	1	8							8
71	8	D	1	11							11
72	7	C	2	29		17	12				
73	8	F	1	8							8
74	8	F	1	24							24
75	8	D	1	10							10
76	8	F	1	11							11
77	8	F	1	9							9
78	8	D	1	11			11				
79	8	F	1	4							4
80	8	F	1	10							10

81	8	F	1	9							9
82	7	B	2	25	11					14	
83	7	B	2	26	14				12		
84	7	B	1	6	6						
85	7	B	1	41	41						
86	7	C	1	8					8		
87	3	A	1	8			8				
88	3	A	1	18					18		
89	3	A	1	8					8		
90	7	B	1	3					3		
91	7	B	1	9					9		
92	7	B	1	14					14		
93	5	D	2	100		24		76			
94	5	D	1	50	50						
95	6	A	1	33					33		
96	6	A	1	21					21		
97	6	A	1	36					36		
98	6	A	1	6					6		
99	6	A	1	75					75		
100	6	A	1	50					50		
101	6	A	1	7					7		
102	6	A	1	74					74		
103	5	D	2	31	27						4
104	5	D	1	22	22						
105	5	D	1	11	11						
106	5	D	1	41	41						
107	5	D	1	30	30						
108	5	D	1	11							11
109	5	D	1	49							49
110	5	A	1	10			10				
111	5	D	3	51					27	6	18
112	5	B	1	22	22						
113	5	C	1	19					19		
114	5	E	1	39					39		
115	3	A	1	28					28		
116	3	A	4	101			43	5	44	9	
117	6	B	1	107	107						
118	6	B	1	78	78						
119	6	B	1	29	29						
120	6	B	1	5	5						
121	7	B	1	11					11		
122	7	B	1	11					11		
123	6	B	1	77	77						

124	6	B	1	11		11				
125	7	B	1	12					12	
126	6	B	1	11		11				
127	7	B	1	14					14	
128	6	B	1	22		22				
129	6	B	1	9		9				
130	6	B	1	14		14				
131	7	B	1	26					26	
132	7	B	1	9					9	
133	6	C	1	3		3				
134	6	C	1	19		19				
135	6	C	1	25		25				
136	7	B	4	466	130		44	247	45	
137	7	D	1	30	30					
138	8	G	1	18					18	
139	8	G	1	31					31	
140	8	G	3	83		33			21	29

Appendix M: Quantitative Data from Nighttime Observations

Results from Monday, January 22, 2007

Survey ID	Section	Block	Time	Total Illuminated Windows	Windows per Façade							
					N	NE	E	SE	S	SW	W	NW
41	1	A	22:20	43	12				10		18	3
42	1	A	22:19	76	51				25			
40	1	B	22:21	2		2						
1	1	C	22:06	102	7				7		88	
39	1	D	22:40	15		15						
2	1	E	22:50	0		0						
3	1	E	22:47	42		25						17
4	1	E	22:47	0		0						
26	1	E	22:44	0				0	0	0		
43	2	A	23:28	54		39		15				
27	2	B	23:22	12		3		9				
6	2	C	23:15	14		10		4				
28	2	C	23:20	72				37		35		
5	2	D	22:54	58						54		4
11	2	E	00:37	44		33						11
51	2	E	00:36	0		0		0				
7	2	F	23:10	28		4		13				11
8	2	F	23:00	0						0		0
9	2	F	23:10	0						0		
10	2	F	23:12	5						5		
50	3	A	23:51	11		11						
87	3	A	23:48	0				0				
88	3	A	23:50	0				0				
89	3	A	23:51	0						0		
115	3	A	23:41	10						10		
116	3	A	23:42	18				15	0	0	3	
29	3	B	00:00	42		23						19
30	3	B	00:07	7		7						
31	3	B	00:10	22		10	2	10				
44	3	B	23:56	49						28		21
45	3	B	23:57	52				28		24		
47	3	B	23:05	10				10				
32	3	C	00:15	18						6		12
33	3	C	00:20	24		24						
34	3	C	00:22	18				13		5		

37	3	C	00:24	0				0				
46	3	C	23:53	16						9		7
48	3	C	00:11	0						0		
49	3	C	23:52	6						6		
38	4	A	01:04	0		0						
36	4	B	01:06	4	0	1						3
23	4	C	01:00	1				1		0		
24	4	C	01:01	6.5						6.5		
25	4	C	01:02	0						0		
35	4	C	01:05	12						12		
52	4	D	00:50	11								11
53	4	D	00:52	13								13
56	4	D	00:56	15				8	7			
55	9	A	01:13	24	1	11				3	1	8
57	9	A	01:13	2		0				2		
58	9	A	01:20	31		31						
54	9	B	01:15	64						35		29
59	9	B	01:21	1						1		
18	9	C	01:36	0				0				
19	9	C	01:35	0				0				
60	9	C	01:22	14								14
12	9	D	01:37	0		0		0		0		
13	9	D	01:47	32		32				0		
14	9	D	01:40	0						0		
15	9	D	01:43	22						22		
16	9	E	01:39	0						0		
17	9	E	01:37	1			1					

Results from Monday, January 29, 2007

Survey ID	Section	Block	Time	Total Illuminated Windows	Windows per Façade							
					N	NE	E	SE	S	SW	W	NW
41	1	A	23:37	2	0				0		2	0
42	1	A	23:26	82	42	12			28			
40	1	B	23:48	1		1						
1	1	C	23:12	84	7				7		70	
39	1	D	23:51	3		3						
2	1	E	0:25	0		0						
3	1	E	0:23	42		25						17
4	1	E	0:22	0		0						
26	1	E	0:20	0				0	0	0		
43	2	A	1:35	66		56		10				
27	2	B	1:25	6		6		0				
6	2	C	0:30	5		5		0				
28	2	C	1:06	19				19		0		
5	2	D	0:28	5						1		4
11	2	E	0:47	24		10						14
51	2	E	0:50	1		1		0				
7	2	F	0:38	34		22		8				4
8	2	F	0:35	0						0		0
9	2	F	0:36	0						0		
10	2	F	1:02	5						5		
50	3	A	2:03	12		12						
87	3	A	2:06	0				0				
88	3	A	2:07	0						0		
89	3	A	2:08	0						0		
115	3	A	2:12	11						11		
116	3	A	2:10	19				15	1	1	2	
29	3	B	1:28	40		26						14
30	3	B	1:51	7		7						
31	3	B	1:54	16		10	2	4				
44	3	B	2:31	36						13		23
45	3	B	1:44	21				13		8		
47	3	B	1:44	10				10				
32	3	C	1:50	4		0						4
33	3	C	1:58	4		4						
34	3	C	2:00	2		1		1				
37	3	C	2:02	0				0				
46	3	C	1:45	8						2		6
48	3	C	1:53	0						0		
49	3	C	1:47	0						0		
38	4	A	2:16	0		0						
36	4	B	2:21	0	0	0						0
23	4	C	2:23	0				0		0		
24	4	C	2:22	5						5		
25	4	C	2:20	0						0		

35	4	C	2:19	8					8		
52	4	D	0:55	17							17
53	4	D	0:59	7							7
56	4	D	2:34	9			6	3			
55	9	A	2:28	21	1	12			1	1	6
57	9	A	2:42	0		0			0		
58	9	A	2:43	15		15					
54	9	B	2:33	78					51		27
59	9	B	2:40	1					1		
18	9	C	2:54	0			0				
19	9	C	2:53	1			1				
60	9	C	2:45	32							32
12	9	D	3:09	0		0	0		0		
13	9	D	3:01	13		13			0		
14	9	D	3:07	0					0		
15	9	D	3:05	21					21		
16	9	E	2:54	0					0		
17	9	E	2:55	1		1			0		

Results from Thursday, February 8, 2007

Survey ID	Section	Block	Time	Total Illuminated Windows	Windows per Façade N	NE	E	SE	S	SW	W	NW
110	5	A	22:11	2					2			
112	5	B	22:21	1		1						
113	5	C	22:23	3						3		
93	5	D	22:31	24			4		20			
94	5	D	22:29	10		10						
103	5	D	22:44	7		7						0
104	5	D	22:42	1		1						
105	5	D	22:41	1		1						
106	5	D	22:40	7		7						
107	5	D	22:38	0		0						
108	5	D	22:45	10								10
109	5	D	22:13	8								8
111	5	D	22:17	0						0	0	0
114	5	E	22:25	17						17		
95	6	A	22:51	0						0		
96	6	A	22:56	5						5		
97	6	A	22:53	0						0		
98	6	A	22:52	0						0		
99	6	A	22:51	0						0		
100	6	A	22:50	16						16		
101	6	A	22:49	1						1		
102	6	A	22:48	67						67		
117	6	B	23:13	28		28						
118	6	B	23:12	5		5						
119	6	B	23:11	12		12						
120	6	B	23:10	3		3						
123	6	B	23:08	0		0						
124	6	B	23:14	0		0						
126	6	B	23:10	0		0						
128	6	B	23:09	6		6						
129	6	B	23:08	4		4						
130	6	B	23:04	5		5						
133	6	C	23:27	0		0						
134	6	C	23:29	5		5						
135	6	C	23:31	2		2						
63	7	A	0:28	4		4						
65	7	A	0:22	13		13						

66	7	A	0:22	9				9			
67	7	A	0:26	5		5					
82	7	B	0:32	6		6					
83	7	B	0:40	6		6					
84	7	B	0:39	0		0					
85	7	B	0:35	0		0					
62	7	B	23:48	4		4					
90	7	B	23:19	0						0	
91	7	B	23:20	0						0	
92	7	B	23:21	0						0	
121	7	B	23:16	6						6	
122	7	B	23:18	1						1	
125	7	B	23:22	0						0	
127	7	B	23:24	5						5	
131	7	B	23:25	0						0	
132	7	B	23:25	0						0	
136	7	B	23:32	56	17		7		25	7	
72	7	C	0:16	3		3		0			
86	7	C	0:30	6						6	
137	7	D	23:35	12							12
22	8	A	0:45	8		6		2			
64	8	A	0:24	0						0	
21	8	B	0:40	4						4	
68	8	C	0:20	0						0	
69	8	C	0:21	0						0	
70	8	D	0:18	0							0
71	8	D	0:19	0							0
75	8	D	0:05	1							1
78	8	D	0:06	0							0
20	8	E	23:55	66		40		8		18	
61	8	F	23:49	12				12			
73	8	F	0:03	0							0
74	8	F	0:00	2							2
76	8	F	0:07	1							1
77	8	F	0:08	0							0
79	8	F	0:10	1							1
80	8	F	0:12	2							2
81	8	F	0:14	0							0
138	8	G	23:41	1						1	
139	8	G	23:45	7						7	
140	8	G	23:46	28		19				6	3

Results from Monday, February 12, 2007

Survey ID	Section	Block	Time	Total Illuminated Windows	Windows per Façade N	NE	E	SE	S	SW	W	NW
110	5	A	22:48	2					2			
112	5	B	22:51	5		5						
113	5	C	22:53	2						2		
93	5	D	23:00	28			7		21			
94	5	D	23:02	5		5						
103	5	D	22:44	9		8						1
104	5	D	23:10	0		0						
105	5	D	23:11	1		1						
106	5	D	23:12	1		1						
107	5	D	23:13	0		0						
108	5	D	22:46	6								6
109	5	D	22:47	9								9
111	5	D	22:49	0						0	0	0
114	5	E	22:57	19						19		
95	6	A	23:04	1						1		
96	6	A	23:05	3						3		
97	6	A	23:07	0						0		
98	6	A	23:09	1						1		
99	6	A	23:09	0						0		
100	6	A	23:10	2						2		
101	6	A	23:11	1						1		
102	6	A	23:13	4						4		
117	6	B	23:13	16		16						
118	6	B	23:14	1		1						
119	6	B	23:16	10		10						
120	6	B	23:15	2		2						
123	6	B	23:16	0		0						
124	6	B	23:20	0		0						
126	6	B	23:25	0		0						
128	6	B	23:25	11		11						
129	6	B	23:26	4		4						
130	6	B	23:27	1		1						
133	6	C	23:38	0		0						
134	6	C	23:39	5		5						
135	6	C	23:40	4		4						
63	7	A	0:25	2		2						
65	7	A	0:20	17		17						
66	7	A	0:22	17				17				

67	7	A	0:14	1		1						
82	7	B	0:13	11		11						
83	7	B	0:15	9		9						
84	7	B	0:16	0		0						
85	7	B	0:35	6		6						
62	7	B	0:12	7		7						
90	7	B	23:31	0						0		
91	7	B	23:32	0						0		
92	7	B	23:32	0						0		
121	7	B	23:29	0						0		
122	7	B	23:30	1						1		
125	7	B	23:32	0						0		
127	7	B	23:33	6						6		
131	7	B	23:34	0						0		
132	7	B	23:35	2						2		
136	7	B	23:37	64	33		8		20	3		
72	7	C	0:10	5		5		0				
86	7	C	0:18	9						9		
137	7	D	23:46	10								10
22	8	A	0:32	9		7		2				
64	8	A	0:26	0						0		
21	8	B	0:31	1						1		
68	8	C	0:27	0						0		
69	8	C	0:29	0						0		
70	8	D	0:29	0								0
71	8	D	0:30	0								0
75	8	D	0:07	0								0
78	8	D	0:07	0								0
20	8	E	23:55	57		31		8		18		
61	8	F	23:55	12				12				
73	8	F	0:02	1								1
74	8	F	0:03	6								6
76	8	F	0:07	0								0
77	8	F	0:08	0								0
79	8	F	0:10	1								1
80	8	F	0:10	0								0
81	8	F	0:10	0								0
138	8	G	23:48	1						1		
139	8	G	23:50	7						7		
140	8	G	23:51	50	2	12				13	4	19

Appendix N: Power Consumption for Lighting

Based on Data from Monday, January 22, 2007

Survey ID	Section	Block	Illuminated Windows in Building (%)	Illuminated Floor Space (m^2)	Power Consumption (kW)
41	1	A	87.76	1281.93	16.02
42	1	A	63.33	2784.13	34.80
40	1	B	7.14	27.45	0.34
1	1	C	30.72	4653.90	58.17
39	1	D	38.46	251.54	3.14
2	1	E	0.00	0.00	0.00
3	1	E	100.00	1656.40	20.71
4	1	E	0.00	0.00	0.00
26	1	E	0.00	0.00	0.00
43	2	A	17.42	1351.39	16.89
27	2	B	8.63	236.50	2.96
6	2	C	20.00	743.50	9.29
28	2	C	68.57	2465.14	30.81
5	2	D	93.55	3806.58	47.58
11	2	E	29.14	888.16	11.10
51	2	E	0.00	0.00	0.00
7	2	F	11.20	1007.44	12.59
8	2	F	0.00	0.00	0.00
9	2	F	0.00	0.00	0.00
10	2	F	27.78	399.56	4.99
50	3	A	44.00	344.26	4.30
87	3	A	0.00	0.00	0.00
88	3	A	0.00	0.00	0.00
89	3	A	0.00	0.00	0.00
115	3	A	35.71	2038.43	25.48
116	3	A	17.82	578.23	7.23
29	3	B	28.77	788.45	9.86
30	3	B	15.56	686.39	8.58
31	3	B	43.14	578.90	7.24
44	3	B	17.69	1255.60	15.70
45	3	B	35.62	973.61	12.17
47	3	B	40.00	696.96	8.71
32	3	C	40.00	1167.04	14.59
33	3	C	47.06	738.07	9.23
34	3	C	46.15	742.15	9.28
37	3	C	0.00	0.00	0.00
46	3	C	48.48	798.55	9.98
48	3	C	0.00	0.00	0.00
49	3	C	19.35	344.67	4.31
38	4	A	0.00	0.00	0.00
36	4	B	12.12	83.21	1.04

23	4	C	1.96	19.84	0.25
24	4	C	54.17	413.73	5.17
25	4	C	0.00	0.00	0.00
35	4	C	80.00	1357.60	16.97
52	4	D	6.67	313.63	3.92
53	4	D	30.95	1294.06	16.18
56	4	D	41.67	586.04	7.33
55	9	A	23.30	608.71	7.61
57	9	A	2.67	89.66	1.12
58	9	A	68.89	1447.08	18.09
54	9	B	20.45	2148.19	26.85
59	9	B	3.70	37.72	0.47
18	9	C	0.00	0.00	0.00
19	9	C	0.00	0.00	0.00
60	9	C	15.38	1061.54	13.27
12	9	D	0.00	0.00	0.00
13	9	D	17.78	716.16	8.95
14	9	D	0.00	0.00	0.00
15	9	D	44.00	2166.52	27.08
16	9	E	0.00	0.00	0.00
17	9	E	5.56	27.50	0.34

Based on Data from Monday, January 29, 2007

Survey ID	Section	Block	Illuminated Windows in Building (%)	Illuminated Floor Space (m^2)	Power Consumption (kW)
41	1	A	4.08	59.62	0.75
42	1	A	68.33	3003.93	37.55
40	1	B	3.57	13.73	0.17
1	1	C	25.30	3832.63	47.91
39	1	D	7.69	50.31	0.63
2	1	E	0.00	0.00	0.00
3	1	E	100.00	1656.40	20.71
4	1	E	0.00	0.00	0.00
26	1	E	0.00	0.00	0.00
43	2	A	21.29	1651.70	20.65
27	2	B	4.32	118.25	1.48
6	2	C	7.14	265.54	3.32
28	2	C	18.10	650.52	8.13
5	2	D	8.06	328.15	4.10
11	2	E	15.89	484.45	6.06
51	2	E	2.22	102.43	1.28
7	2	F	13.60	1223.32	15.29
8	2	F	0.00	0.00	0.00
9	2	F	0.00	0.00	0.00
10	2	F	27.78	399.56	4.99
50	3	A	48.00	375.55	4.69
87	3	A	0.00	0.00	0.00
88	3	A	0.00	0.00	0.00
89	3	A	0.00	0.00	0.00
115	3	A	39.29	2242.27	28.03
116	3	A	18.81	610.35	7.63
29	3	B	27.40	750.90	9.39
30	3	B	15.56	686.39	8.58
31	3	B	31.37	421.02	5.26
44	3	B	13.00	922.48	11.53
45	3	B	14.38	393.19	4.91
47	3	B	40.00	696.96	8.71
32	3	C	8.89	259.34	3.24
33	3	C	7.84	123.01	1.54
34	3	C	5.13	82.46	1.03
37	3	C	0.00	0.00	0.00
46	3	C	24.24	399.27	4.99
48	3	C	0.00	0.00	0.00
49	3	C	0.00	0.00	0.00
38	4	A	0.00	0.00	0.00
36	4	B	0.00	0.00	0.00
23	4	C	0.00	0.00	0.00
24	4	C	41.67	318.25	3.98
25	4	C	0.00	0.00	0.00

35	4	C	53.33	905.07	11.31
52	4	D	10.30	484.70	6.06
53	4	D	16.67	696.80	8.71
56	4	D	25.00	351.63	4.40
55	9	A	20.39	532.63	6.66
57	9	A	0.00	0.00	0.00
58	9	A	33.33	700.20	8.75
54	9	B	24.92	2618.11	32.73
59	9	B	3.70	37.72	0.47
18	9	C	0.00	0.00	0.00
19	9	C	9.09	53.71	0.67
60	9	C	35.16	2426.37	30.33
12	9	D	0.00	0.00	0.00
13	9	D	7.22	290.94	3.64
14	9	D	0.00	0.00	0.00
15	9	D	42.00	2068.04	25.85
16	9	E	0.00	0.00	0.00
17	9	E	5.56	27.50	0.34

Based on Data from Thursday, February 8, 2007

Survey ID	Section	Block	Illuminated Windows in Building (%)	Illuminated Floor Space (m^2)	Power Consumption (kW)
110	5	A	20.00	236.50	2.96
112	5	B	4.55	29.04	0.36
113	5	C	15.79	90.87	1.14
93	5	D	24.00	429.95	5.37
94	5	D	20.00	573.30	7.17
103	5	D	22.58	635.55	7.94
104	5	D	4.55	57.85	0.72
105	5	D	9.09	140.24	1.75
106	5	D	17.07	194.50	2.43
107	5	D	0.00	0.00	0.00
108	5	D	90.91	997.45	12.47
109	5	D	16.33	368.83	4.61
111	5	D	0.00	0.00	0.00
114	5	E	43.59	902.31	11.28
95	6	A	0.00	0.00	0.00
96	6	A	23.81	1007.43	12.59
97	6	A	0.00	0.00	0.00
98	6	A	0.00	0.00	0.00
99	6	A	0.00	0.00	0.00
100	6	A	32.00	1143.68	14.30
101	6	A	14.29	179.57	2.24
102	6	A	90.54	4072.15	50.90
117	6	B	26.17	1033.51	12.92
118	6	B	6.41	234.36	2.93
119	6	B	41.38	609.72	7.62
120	6	B	60.00	448.20	5.60
123	6	B	0.00	0.00	0.00
124	6	B	0.00	0.00	0.00
126	6	B	0.00	0.00	0.00
128	6	B	27.27	404.18	5.05
129	6	B	44.44	564.89	7.06
130	6	B	35.71	930.00	11.63
133	6	C	0.00	0.00	0.00
134	6	C	26.32	1273.68	15.92
135	6	C	8.00	173.12	2.16
63	7	A	30.77	193.16	2.41
65	7	A	61.90	772.82	9.66
66	7	A	52.94	56.69	0.71
67	7	A	50.00	786.60	9.83
62	7	B	30.00	736.56	9.21
82	7	B	24.00	222.05	2.78
83	7	B	0.00	0.00	0.00
84	7	B	0.00	0.00	0.00
85	7	B	9.76	107.12	1.34

90	7	B	0.00	0.00	0.00
91	7	B	0.00	0.00	0.00
92	7	B	0.00	0.00	0.00
121	7	B	54.55	718.91	8.99
122	7	B	9.09	40.80	0.51
125	7	B	0.00	0.00	0.00
127	7	B	35.71	417.43	5.22
131	7	B	0.00	0.00	0.00
132	7	B	0.00	0.00	0.00
136	7	B	12.02	1032.15	12.90
72	7	C	10.34	33.13	0.41
86	7	C	75.00	365.70	4.57
137	7	D	40.00	4588.64	57.36
22	8	A	38.10	83.74	1.05
64	8	A	0.00	0.00	0.00
21	8	B	14.29	270.91	3.39
68	8	C	0.00	0.00	0.00
69	8	C	0.00	0.00	0.00
70	8	D	0.00	0.00	0.00
71	8	D	0.00	0.00	0.00
75	8	D	10.00	22.45	0.28
78	8	D	0.00	0.00	0.00
20	8	E	16.54	1339.55	16.74
61	8	F	12.00	570.82	7.14
73	8	F	0.00	0.00	0.00
74	8	F	8.33	239.10	2.99
76	8	F	9.09	31.98	0.40
77	8	F	0.00	0.00	0.00
79	8	F	25.00	95.55	1.19
80	8	F	20.00	65.11	0.81
81	8	F	0.00	0.00	0.00
138	8	G	5.56	78.78	0.98
139	8	G	22.58	544.92	6.81
140	8	G	33.73	1093.52	13.67

Based on Data from Monday, February 12, 2007

survey ID	Section	Block	Illuminated Windows in Building (%)	Illuminated Floor Space (m^2)	Power Consumption (kW)
110	5	A	20.00	236.50	2.96
112	5	B	22.73	145.19	1.81
113	5	C	10.53	60.58	0.76
93	5	D	28.00	501.60	6.27
94	5	D	10.00	286.65	3.58
103	5	D	29.03	817.14	10.21
104	5	D	0.00	0.00	0.00
105	5	D	9.09	140.24	1.75
106	5	D	2.44	27.79	0.35
107	5	D	0.00	0.00	0.00
108	5	D	54.55	598.47	7.48
109	5	D	18.37	414.93	5.19
111	5	D	0.00	0.00	0.00
114	5	E	48.72	1008.46	12.61
95	6	A	3.03	101.44	1.27
96	6	A	14.29	604.46	7.56
97	6	A	0.00	0.00	0.00
98	6	A	16.67	276.28	3.45
99	6	A	0.00	0.00	0.00
100	6	A	4.00	142.96	1.79
101	6	A	14.29	179.57	2.24
102	6	A	5.41	243.11	3.04
117	6	B	14.95	590.58	7.38
118	6	B	1.28	46.87	0.59
119	6	B	34.48	508.10	6.35
120	6	B	40.00	298.80	3.74
123	6	B	0.00	0.00	0.00
124	6	B	0.00	0.00	0.00
126	6	B	0.00	0.00	0.00
128	6	B	50.00	741.00	9.26
129	6	B	44.44	564.89	7.06
130	6	B	7.14	186.00	2.33
133	6	C	0.00	0.00	0.00
134	6	C	26.32	1273.68	15.92
135	6	C	16.00	346.24	4.33
63	7	A	15.38	96.58	1.21
65	7	A	80.95	1010.61	12.63
66	7	A	100.00	107.08	1.34
67	7	A	10.00	157.32	1.97
62	7	B	44.00	1080.29	13.50
82	7	B	34.62	320.26	4.00
83	7	B	0.00	0.00	0.00
84	7	B	14.63	178.01	2.23
85	7	B	35.00	384.30	4.80

90	7	B	0.00	0.00	0.00
91	7	B	0.00	0.00	0.00
92	7	B	0.00	0.00	0.00
121	7	B	0.00	0.00	0.00
122	7	B	9.09	40.80	0.51
125	7	B	0.00	0.00	0.00
127	7	B	42.86	500.91	6.26
131	7	B	0.00	0.00	0.00
132	7	B	22.22	628.53	7.86
136	7	B	13.73	1179.61	14.75
72	7	C	17.24	55.22	0.69
86	7	C	100.00	487.60	6.10
137	7	D	33.33	3823.87	47.80
22	8	A	42.86	94.20	1.18
64	8	A	0.00	0.00	0.00
21	8	B	3.57	67.73	0.85
68	8	C	0.00	0.00	0.00
69	8	C	0.00	0.00	0.00
70	8	D	0.00	0.00	0.00
71	8	D	0.00	0.00	0.00
75	8	D	0.00	0.00	0.00
78	8	D	0.00	0.00	0.00
20	8	E	14.29	1156.89	14.46
61	8	F	12.00	570.82	7.14
73	8	F	12.50	45.53	0.57
74	8	F	25.00	717.30	8.97
76	8	F	0.00	0.00	0.00
77	8	F	0.00	0.00	0.00
79	8	F	25.00	95.55	1.19
80	8	F	0.00	0.00	0.00
81	8	F	0.00	0.00	0.00
138	8	G	5.56	78.78	0.98
139	8	G	22.58	544.92	6.81
140	8	G	60.24	1952.71	24.41

Appendix O: Results from Detailed Observation

Building Survey ID #34
Conducted on Monday, 12 February 2007 at 10 pm

Field Notes from the Observation

- The night manager indicated that he is responsible for energy conservation. He turns lights off in areas when people leave.

- We conducted the detailed observation on floor 3 of the building.

- Notes on the stairwells:
  - There are two stairwells in the building. We were able to observe the Whitfield Street stairwell, which we did not include in our external observations of the building.
  - We included the windows of the stairwell on the Tottenham Street façade in our regular building data.
  - Lights are left on in stairwells whenever people may need to use them. The building manager turns off the lights if no one is in the building.
  - There is a light switch on every landing in the stairwell which controls all the lights in the stairwell. The switches are located right next to the door each floor.
  - Light bulbs used in the stairwells are 60W incandescent bulbs.
  - There are 5 bulbs on every floor in the stairwell.
  - There are 6 floors in the stairwell.

- Notes on open plan offices:
  - There are open plan offices in the floors above the lobby.
  - There are four offices along the Tottenham Street façade of the building that extend approximately 2/3 down the length of the office. They occupy approximately 1/5 of the floors space in the office. There is an office with an entrance at the rear of the open plan office, which is not visible from either of the façades we observed.
  - The offices will be referred to as A, B, C, and D, with A being closest to the Whitfield St. façade. The office in the back of the building will be referred to as the back office or Office E.
  - The building manager puts only one light bulb into each lamp, when two would fit. He says that including all the bulbs makes the room much more bright than necessary, which is a waste of energy. Furthermore, people complain that it is too bright in the room if all the bulbs are included.
  - Light bulbs used in the offices are Energy rating B. Model: OSRAM Basic L75W/535
  - The bulbs are 75W, 6400 Lumen fluorescent tubes

- Notes on people working:
  - People typically work late or through the night at this company.

- When we conducted this observation, there were two people working in the open plan office on the second floor.
- There were no people working on the third floor, but all the light switches were turned on.

- Notes on light switches:
  - The lighting panel for the room is located by exit to the main stairwell.
  - 6 light switches control all the ceiling lights on one floor.
  - One light switch controls only the lights in two one of the offices.
  - Another light switch controls only the lights in a part of the room and two of the offices.
  - The rest of the light switches control lights on individual columns of ceiling lights that extend the length of the room.
  - Unsure about where the light switch is for the remaining office, which is the second closes to the Whitfield St. façade.

- Layout of lights and windows:
  - Open plan
    - 41 lights bulbs were illuminated out of 48 total lights.
    - 1 light of the same type was on in the room near a back closet
    - Some light bulbs were burned out. (the number of total lights assumes that only 1 light bulb will be installed in each lamp, which is the practice in the building).
    - 2 windows on Tottenham St. façade
    - 1 window on Whitfield St. façade
  - Office A:
    - 4 of 4 light bulbs were on
    - 1 window
  - Office B:
    - 0 of 4 light bulbs were on
    - 1 window
  - Office C:
    - 2 of 2 light bulbs were on
    - 1/3 window (window shared with office D)
  - Office D:
    - 1 of 2 light bulbs were on
    - 2/3 window (window shared with office C)
  - Office E:
    - 2 of 3 light bulbs were on
    - 1 window, not visible from the street.

- Notes from the outside observation:
  - Tottenham Street façade:
    - All windows illuminated on floor 2
    - All windows illuminated on floor 3
    - 2 windows illuminated on floor 4

        - 12 of 15 total office windows illuminated
        - Left-side stairwell has 10/10 windows illuminated
        - 1/3 windows on ground floor illuminated
    - Whitfield Street façade:
        - 3 of 4 office windows lit
        - Stairwell is illuminated
        - 1 window on ground floor (lobby is illuminated)

Quantitative Results from the Observation

- Total number of light bulbs were on on floor 3: 51
- Area per floor: 321.6 m^2 (from existing CaRB data)
- Comparison of power consumption estimates for floor 3:
    - Power used for lighting the floor: 51 bulbs x 75 w/bulb = 3825 W
    - Power density for lighting is (51 bulbs x 75 w/bulb) / 321.6 m^2/floor = 11.9 W/m^2
    - Our estimate of power used on floor 3:
    (6 windows illuminated / 6 total windows) x 12.5 W/m^2 x 321.6 m^2/floor = 4020 W
    - The estimated error is (4020-3825) / 3825 = 5.10% for the floor.
- Comparison of estimates of power consumption per window:
    - There are 51 bulbs / 6 windows on each floor = 8.5 bulbs / window
    - With measured results: 8.5 bulbs/window x 75 W/bulb = 637.5 W / window
    - With assumed power density: 4020 W / 6 windows = 670 W / window
- Comparison of estimates of only office space in the building:
    - Detailed measurement of energy consumption in building for office space only:
    637 W/window x 15 windows = 9555 W
    - Calculation with our methodology considering office windows only:
    15 windows illuminated / 24 windows total x 321.6 m^2/floor x 4 floors x 12.5 W/m^2 = 10050 W
    - The estimated error is (10050-9555) / 9555 = 5.18% for office windows only.
- Comparison of estimates of power consumption for the entire building:

- We could not access the Tottenham Street stairwell during our detailed observation. We included this stairwell in our data of illuminated windows during our regular observations of this building. Since we only have detailed data on the Whitfield Street stairwell, we make the assumption that both stairwells use the same type and number of bulbs for this comparison.

- We could not identify the types of bulbs on the ground floor, so we assume that the lobby has the same power density as we measured in the office space. We estimate the power consumption from lighting the ground floor to be:
  3 illuminated windows / 6 windows x 321.6 m^2 x 11.9 W/m^2 = 1913 W

- Power consumption in the Whitfield Street stairwell:
  5 bulbs/floor x 6 floors x 60 W/bulb = 1800 W

- Estimate of power consumption with data from detailed observation:
  9555 W in office space + 1800 W in stairwell + 1913 W on ground floor
  = 13268 W

- Estimate of power consumption with our methodology including stairwell and lobby:
  25 / 34 windows illuminated x 321.6 m^2/floor x 4 floors x 12.5 W/m^2
  = 11824 W

- The estimated error is (13268-11824) / 13268 = 10.9% for the whole building.

Appendix P: Building Manager Interview Responses

Interview 1

Date: 30/01/07
Time: 10:30
Building Survey ID# 17
Interviewer: Tom Niemczycki
Scribe: Vanessa Walton

1. **What is your position in this building?**

Service manager

2. **Do you ever see the building or are here at night?**

Yes, I have seen the building at night, however not in the middle of the night. Some people in the office do work late at night.

3. **Can you provide us with any of the following building specifications:**

    a. **What are the primary uses of this building?**

    Office space

    b. **How are the floors laid out? (Open plane or cellular)?**

    The Morwell St Office building is open plan, however the rest of the buildings are cellular.

    c. **How many rooms per floor?**

    It varies rooms per floor on each floor. I would say 4 average rooms per floor.

    d. **What is the average size of the rooms?**

    Varies

    e. **During which hours of the day is the building occupied?**

    People start coming in at 07:00; however lights are on before then around 05:30/06:00. Most buildings have lights on at this time because it's still dark out.

4. **How late do people typically work in this building?**

People work from 09:00-17:30 (supposed to), however it depends on how late they stay.

5. **Are there cleaners who come in at night? If yes, what time of the night and for how long?**

Cleaners come in 17:30-19:00

6. **Are there lights left on in this building at night?**

Lights are probably left on at night.

7. If yes, why?

People just forget to turn them off.

8. Which rooms or areas are lit overnight?

Random room lights are left on at night.

9. Where are the light switches located for this office space?

The light switches are near the doors.

10. What kinds of switches are there? (e.g. motion sensors)

Regular light switches.

11. Does one switch turn on all the lights?

No.

12. Are people asked to turn the lights off if they are the last to leave the office?

Cleaners are supposed to turn the lights off. Hallway lights are left on because of the cameras in the hallway need light to operate.

13. Are there any other activities that go on at night that require lighting?

Sometimes employees stay to work late.

14. What types of light bulbs are used?

We try to use long-life bulbs, fluorescent. Rooms have different mixture of bulbs.

15. About how many light bulbs are used in each room?

There is a big mixture of how many bulbs used. Higher ceilings require more light.

16. Do you have an estimate of how much energy is used by lighting in this building?

A lot of energy…for the electric bills, it's about £1500-2000 a month. We sometimes pay quarterly and monthly, but it depends. In the summer the electricity goes down. This building is less because different rooms have different lights on/off.

Interview 2

Date: 06/02/07
Time: 11:00
Survey ID# 21
Interviewer: Jonathan Levin
Scribe: Vanessa Walton

1. **What is your position in this building?**

Operations executive; I look after the building, and make sure everything runs smoothly.

2. **Can you provide us with any of the following building specifications:**

    a. **What are the primary uses of this building?**

    The ground floor and first floor are used for media advertising.

    b. **How are the floors laid out? (Open plane or cellular)?**

    The floors are divided by room, and vary by floor.

3. **Do you ever see the building or are here at night?**

Very occasionally, we turn the lights off at night.

4. **During which hours of the day is the building occupied?**

Usually 9-6, but probably more around the range of 8-7

5. **Are there cleaners who come in at night? If yes, what time of the night and for how long?**

Cleaners arrive 5:30 am, and stay for a couple of hours.

6. **Are there lights left on in this building at night?**

No

7. **If yes, why?**

There is no reason for the lights to be on at night because no one is here.

8. **Where are the light switches located for this office space?**

Near the doors

9. **What kind of switches are there?**

Regular switches

10. **Are people asked to turn the lights off if they are the last to leave the office?**

No, they turn them off by habit

11. **Are there any other activities that go on at night that require lighting?**

Some people work on the weekends

12. What types of light bulbs are used?

Compact fluorescent bulbs

13. About how many light bulbs are used in each room?

Depends on the size of the room

14. Do you have an estimate of how much energy is used by lighting in this building?

No clue

Note: This building manager sent a follow-up email to the team on February 7, 2007. The email indicated that between July and October 2006, the building used 21458 units of energy.

Interview 3

Date: 07/02/07
Time: 11:00
Survey ID# 34
Interviewer: Jonathan Levin
Scribe: Vanessa Walton

1. **What is your position in this building?**

Administrative manager

2. **Can you provide us with any of the following building specifications:**

    1. **What are the primary uses of this building?**

    Television production

    2. **How are the floors laid out? (Open plane or cellular)?**

    80% of the building is open plan, while 20% is cellular

3. **Do you ever see the building or are here at night?**

Have been here at night, but am not always here at night; usually leave here at 7:00pm.

4. **During which hours of the day is the building occupied?**

All hours of the day

5. **How late do people typically work in this building?**

People are here working all hours of the day. There are log-in sheets that record the hours people come in and when people leave the building and whether they turn off lights or not.

6. **Are there cleaners who come in at night? If yes, what time of the night and for how long?**

Cleaners arrive 5:30am, and during the winter we need to switch the lights on for them, however if the cleaners do not come in, the lights are switched on at 7:30am.

7. **Are there lights left on in this building at night?**

Lights are left on because staff is still working. However from 12-5am the lights are switched off when people are not working.

8. **If yes, why?**

People are working late at night, or through the night.

9. **Where are the light switches located for this office space?**

There is one big panel that contains all the light switches.

10. What kind of switches are there?

Regular switches

11. Does one switch turn on all the lights?

No. There are multiple switches on one panel.

12. Are people asked to turn the lights off if they are the last to leave the office?

In the past we have sent out group e-mails to the company to turn lights off when they leave. There hasn't been any sent out recently but I will send out one today. I sweep the building when I leave at 7:00pm to make sure lights are off that need to be. If I see a room with lights on and only a few people working I shut off about 70% of the lights on the panel.

13. Are there any other activities that go on at night that require lighting?

Some people stay late to work.

14. What types of light bulbs are used?

Fluorescent tubes, 28 watt bulbs

15. About how many light bulbs are used in each room?

In the open plan offices there are about 90-100 lights used.

16. Do you have an estimate of how much energy is used by lighting in this building?

The average energy bill (EDP) for each month is £3500, however for the month of January the bill was £3210.55.

Month	Bill amount
March 2006	£3795
September 2006	£3229
November 2006	£3169
December 2006	£2822
January 2007	£3210.55

We also talked to the IT person, Scott, who gave us information on energy conservation equipment that they are trying to place in the building called "Power Out." It is an automated PC power down system. Scott mentioned that there are about 130 computers in the building and that half of them are left on at night. The computers take up 60-70% of the energy consumption, and lighting takes up roughly 25% of the lighting.

Interview 4

Date: 07/02/07
Replies from E-mailed Questionnaire
Survey ID#13

1. **What is your role in this building?**

   Building Controller

2. **Can you provide us with any of the following building specifications:**

   a. **What are the primary uses of this building?**

      Offices

   b. **How much of the building is used for non-domestic activities?**

      All

   c. **How are the floors laid out (open plan or cellular)?**

      Open plan

   d. **How many rooms per floor?**

      Open plan

   e. **What is the average size of the rooms?**

      Open plan

3. **Do you ever see the building at night?**

   Yes

4. **During which hours of the day is the building occupied?**

   Office hours

5. **How late do people typically work in this building?**

   7pm

6. **Are there cleaners who come in at night? If yes, do you know what time of the night and for how long?**

   Yes - early morning - 3 hours

7. **Are there lights left on in this building at night? Please indicate why or why not.**

   No - not required

8. **Which rooms or areas are lit overnight?**

   Reception only

9. Where are the light switches located for office spaces?

Main Exit

10. What kinds of switches are there? (e.g. motion sensors)

Standard

11. Does one switch turn on all the lights in a room?

Yes

12. Are people asked to turn the lights off if they are the last to leave the office?

Yes

13. Are there any other activities that go on at night that require lighting?

No

14. What types of light bulbs are used?

Varies - mostly flouros and halogen

15. About how many light bulbs are used in each room?

50 per floor (open plan)

16. Do you have an estimate of how much energy is consumed by lighting in this building?

Not to hand

Appendix Q: Relevant Field Notes

This appendix provides select field notes from our nighttime observations.

Notes on People Visible in Buildings during Observations

This section specifies instances where we noted people present in buildings during our overnight observations (excluding security guards in lobbies).

Observation on Monday, January 22, 2007:

- Building Survey ID 39: At least 2 people present and working
- Building Survey ID 50: People present on first floor
- Building Survey ID 115: People painting office on second floor

Observation on Monday, January 29, 2007:

- Building Survey ID 50: People visible on floors 2 and 3

Observation on Thursday, February 8, 2007:

- Building Survey ID 114: People visible on second floor
- Building Survey ID 128: Person visible
- Building Survey ID 122: Person visible
- Building Survey ID 136: Person visible

Observation on Monday, February 12, 2007:

- Building Survey ID 112: Person visible
- Building Survey ID 136: Person visible

Notes on Illuminated Stairwells

This section provides the number of times we observed an illuminated stairwell during each overnight observation.

Observation on Monday, January 22, 2007: 14

Observation on Monday, January 29, 2007: 13

Observation on Thursday, February 8, 2007: 6

Observation on Monday, February 12, 2007: 11

Appendix R: Commercial Lighting Energy Targets

Code For Lighting
2006

Lighting Energy Targets

Average Installed Power Density per Application

The following table provides targets of average power density for a range of applications with particular maintained task illuminances
and are based on current good practice. The values, have been achieved, using efficient lamp circuits and luminaires in well designed installations. They are base on the following criteria:

- An average sized empty room (Room Index 2.5)
- High room surface reflectances (Ceiling 0.7; Walls 0.5; Floor 0.2)
- High degree of installation maintenance (Luminaires cleaned every year, roo
- surfaces every three years, bulk lamp replacement every 10,000 hours).

It should be noted that the values could be higher or lower where variations in criteria are made

Lamp Type	CIE general colour rendering index (Ra)	Task illuminance (lux)	Average installed power density (W/m^2)
Commercial and other similar application e.g. offices, shops and schools *			
Fluorescent – triphosphor	80 – 90	300	7
		500	11
		750	17
Compact fluorescent	80 – 90	300	8
		500	14
		750	21
Metal halide	60 – 90	300	11
		500	18
		750	27

(Source Society for Light and Lighting, 2006)